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ABSTRACT

This Student Manual for a Solar Heating System curriculum contains 22 units of instructional materials for students to use in a course or courses on solar heating systems (see note). For each unit (task), objectives, assignment sheets, laboratory assignments, information sheets, checkpoints (tests), and job sheets are provided. Materials are set up to be suitable for individualized instruction and include keys to prepared slide sets. The 22 units are organized in four major learning modules covering the following topics: (1) understanding solar systems; (2) designing solar systems; (3) installing solar systems; and (4) maintenance of solar systems. (KC)

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SOLAR HEATING SYSTEMS

STUDENT MANUAL

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MAJOR BLOCK Solar Systems: (Phase A: Basic Understanding) **NAME** ______

TASK Explain the value of solar energy, & principles of solar radiation.

UNIT SA-1 **TIME** (est.) ______ (act.) ______

OBJECTIVE(S) The student will be able to:

1) explain problems with conventional fuel sources
2) explain the advantages & disadvantages of solar energy as an energy source
3) define basic terms associated with solar energy
4) list & describe how different factors affect the amount of solar radiation on earth
5) describe the ideal tilt angle & orientation for a collector at a given latitude for a given application.

START → A-1 → L-1 → C-1 → A-2 → L-2 → W-1 → L-3 → W-2 → L-4 → C-2 → W-3 → W-4 → L-5 → L-6 → C-3 → W-5 → L-7 → C-4

	WRITTEN ASSIGNMENT(S)		**AUDIOVISUAL(S)**
W-1	Information Sheet SA-1-1	A-1	Slide Set SA-1-1
W-2	Assignment SA-1-4	A-2	Slide Set SA-1-2
W-3	Assignment SA-1-6	A-3	
W-4	Information Sheet SA-1-2	A-4	
W-5	Assignment SA-1-8	A-5	
W-6		A-6	
W-7		A-7	

	LABORATORY ASSIGNMENT(S)		**CHECKPOINT(S)**
L-1	Assignment SA-1-1	C-1	Observation
L-2	Assignment SA-1-2	C-2	Progress check (written quiz)
L-3	Assignment SA-1-3	C-3	Observation
L-4	Assignment SA-1-5	C-4	Test (written)
L-5	Assignment SA-1-7	C-5	
L-6	Job Sheet SA-1-1	C-6	
L-7	Assignment SA-1-9	C-7	
L-8		C-8	
L-9		C-9	

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4

ACTIVITY SEQUENCE SHEET

Activity	Flow Chart Number	Description of Activity
Slide Set SA-1-1	A-1	View slide set SA-1-1
Assignment SA-1-1	L-1	Do study exercises on Assignment Sheet SA-1-1
Observation	C-1	Observation (by instructor)
Slide Set SA-1-2	A-2	View slide set SA-1-2
AssignmentSA-1-2	L-2	Do study exercises on Assignment Sheet SA-1-2
Information Sheet SA-1-1	W-1	Read Information Sheet SA-1-1
Assignment SA-1-3	L-3	Do study exercises on Assignment Sheet SA-1-3
Assignment SA-1-4	W-2	Read *Fundamentals*, p. 2-3 to 2-5 (from "Energy reaching the earth" up to "Collector tilt")
Assignment SA-1-5	L-4	Do study exercises on Assignment Sheet SA-1-5
Progress Check	C-2	Written quiz.
Assignment SA-1-6	W-3	Read *Fundamentals*, p. 2-5 to 2-7 (from "Collector tilt" to end of chapter)
Information Sheet SA-1-2	W-4	Read Information Sheet SA-1-2
Assignment SA-1-7	L-5	Do study exercises on Assignment Sheet SA-1-7
Job Sheet SA-1-1	L-6	Do Job Sheet SA-1-1
Observation	C-3	Observation (by teacher)
Assignment SA-1-8	W-5	Read *Fundamentals*, p. 2-2 (section on "Different units of measurement")

Assignment SA-1-9	L-7	Do study exercises on Assignment Sheet SA-1-9
Test	C-4	Written

Solar Vs Conventional Energy

1) Define the following terms:

   a. nonrenewable resource

   b. photovoltaic cell

   c. thermal pollution

2) Pretend you are a salesperson for a company that designs, installs and services solar heating systems. You are planning an important meeting with a building contractor who is choosing heating systems for a twenty house subdivision. In the space below, list the points you would make to inform him about the disadvantages of using conventional fuels, and the advantages of solar systems, relative to conventional systems. Also, list possible objections to solar systems which the contractor might make, and indicate your response to overcoming each objection.

   After you have outlined your argument, try it out by presenting it to a fellow student, who should assume the role of the building contractor. Ask your instructor to observe your presentation, and evaluate it.

Advantages of solar systems relative to conventional systems:

Possible objections to solar systems and responses to objections:

Disadvantages of conventional fuels:

ASSIGNMENT SHEET SA-1-2

SOLAR ENERGY: BASIC TERMS

1) Indicate whether each of the following illustrates heating primarily by radiation, conduction, or convection.

a. ________________ The top of our head becomes hot when standing in the sun.

b. ________________ The bottom of a pot becomes hot when placed on an electric stove burner.

c. ________________ Our hands are warmed by holding them over an electric burner.

d. ________________ A small room space heater on the floor gradually heats all of the air in the room.

e. ________________ The air in the north-most half of a room is warmed by sunshine which warms the floor only on the south side of the room.

f. ________________ A room filled with people gradually becomes warmer.

2) Define the following terms:

a. solar constant

b. Btu

c. insolation

d. pyrheliometer

SOLAR TIME VERSUS CLOCK TIME

Most of us are accustomed to telling time by use of a clock. In solar system design, however, it is important to recognize that clock time does not necessarily indicate solar time. Solar noon for a given location is the time when the sun is most directly overhead. Solar noon is the time when there is the greatest solar radiation reaching surfaces on earth. Solar noon does not always occur when it is noon according to the clock. Solar noon is closest to clock time noon for locations whose longitude is at the middle of their time zone (the "meridian").

Figure 1 indicates the meridian of each of the time zones in the continental United States.

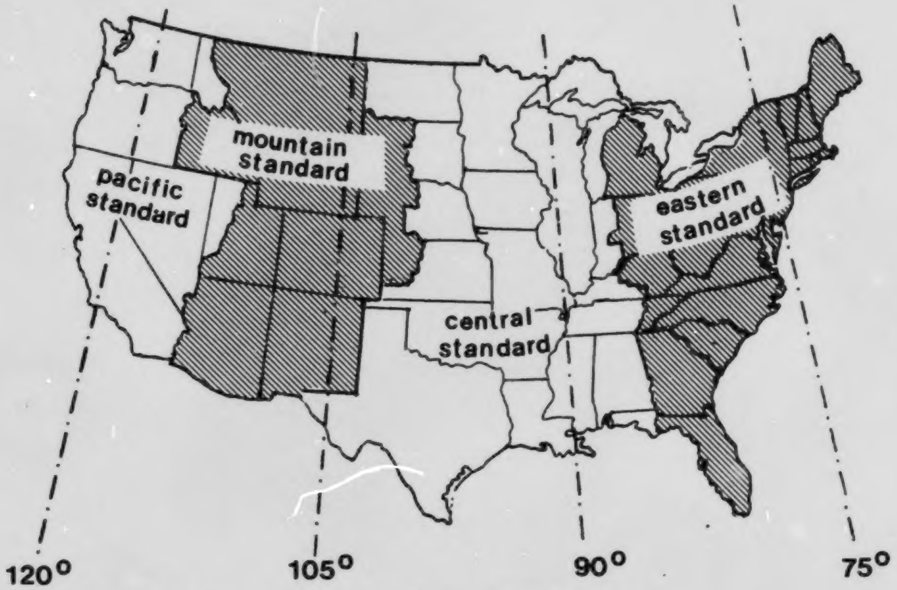

Figure 1. Time Zone Meridians

For locations which are either east or west of their time zone meridian, solar time is slightly different from clock time.

Solar time also differs from clock time because in its daily revolution the earth does not revolve at a constant rate. Figure 2 indicates the amount of time which must be subtracted or added to clock time to correct for variations in the earth's revolution. As can be seen, the correction factor varies from month to month, ranging from zero to sixteen minutes.

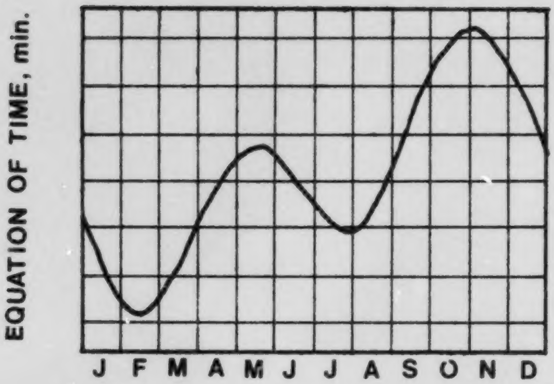

Figure 2. Correction Factors

In designing a solar system, it is important to be able to determine the solar time from clock time. This is particularly important because solar insolation is greatest at true solar noon, rather than at noon according to clock time.

To determine the solar time from clock time for your area, the following steps can be followed:

1) Correction for Daylight Savings Time: If daylight savings time is in effect, subtract one hour from clock time.

2) Correction for local location: Determine the longitude of your locality and the longitude of the standard time meridian (75° for E.S.T, 90° for C.S.T, 105° for M.S.T, and 120° for P.S.T). Multiply the difference between the two by 4 minutes/degree. If your locality is east of the standard meridian, add this correction factor to clock time. If you are west of the standard meridian, subtract this correction factor.

3) Correction for variation in earth's rate of revolution: For each month of the year, Figure 2 indicates the amount of time which should be added or subtracted from clock time.

Example: Determine solar time for Atlanta, Georgia when it is 12 noon clock time in July.

Step 1: 12 noon (clock) - 1 hour = 11 A.M. (clock)

Step 2: Atlanta longitude = 84° 23'

E.S.T meridian = 75°

Difference: = 9° 23'

Difference x 4 minutes/degree =

9° 23' x 4 minutes/degree = 37.5 or 38 minutes

Atlanta is west of the time zone meridian; therefore,

11 A.M. - 38 minutes = 10:22 A.M.

Step 3: Using Figure 2, we see that in July, about 6 minutes more must be subtracted from clock time to obtain solar time.

10:22 A.M. - 6 minutes = 10:16 A.M.

So, when it is noon according to the clock in July in Atlanta, it is really only 10:16 A.M. according to solar time. This means that the solar radiation is greatest not at noon according to clock time, but some time later in the afternoon

ASSIGNMENT SHEET SA-1-3

DETERMINING SOLAR TIME

Problems:

a. What is the longitude for your area? __________

b. Determine the local solar time when it is 12 noon, clock time in May.

c. What clock time corresponds to solar noon in Atlanta in July?

d. What clock time corresponds to solar noon in your area in May?

FACTORS AFFECTING INSOLATION

1) Define the following terms:

   a. solar noon

   b. direct radiation

   c. diffuse radiation

   d. latitude

   e. longitude

2) Is there more insolation in summer or in winter? Why?

3) Is there more insolation on a sunny or cloudy day? Why?

4) Is there more insolation at clock time noon or solar noon? Why?

5) Which receives more solar radiation, the earth's outer atmosphere or the earth's surface? Why is this so?

6) How much heat energy is absorbed by a surface that is 20 x 30 feet at noon on a clear day? Show your calculations.

DETERMINING THE CORRECT TILT ANGLE FOR A GIVEN LATITUDE AND APPLICATION

The latitude of a location describes its distance from the earth's equator. In general, the greater the latitude, the less perpendicular are the sun's rays to horizontal surfaces. Since insolation is greatest when a surface is perpendicular to direct solar radiation, the less the average insolation of a surface at that latitude. For example, a surface in Chicago, which has a latitude of 41°, receives less energy than a surface in Atlanta, with a latitude of 33°.

To increase the solar radiation absorbed by a residential solar collector, the collector is tilted so that it is more perpendicular to the sun's rays. The appropriate tilt angle depends on the latitude and the season in which solar energy is needed. In general, the following tilt angles are recommended:

a. For solar heating only: latitude + 15°

b. For solar cooling only: latitude - 15°

c. For solar heating and cooling, or hot water heating: latitude

SITING SOLAR COLLECTORS

a. Calculate the appropriate tilt angle for solar collectors in Albany, GA. (latitude 31.5°), for the following applications: Show your calculations below.

Solar heating only:

Solar cooling only:

Solar hot water:

b. What is the azimuth angle?

c. In the northern hemisphere, why should solar collectors be positioned facing south?

d. If the solar collectors are oriented 15° west of south, will maximal solar radiation be collected before or after solar noon? Why?

MEASURING OPTIMAL TILT ANGLES

Materials

Firm, flat surface about 8½ x 11"

Cylindrical rod, which can be placed perpendicular to the surface

Pencil

Paper

Protractor

Procedure

Determine the tilt angle for maximal insolation at six different times during the day: early morning, mid-morning, noon, solar noon, early afternoon, late afternoon. A simple procedure for determining optimal tilt angle is the following:

Place the rod on the surface so that it extends perpendicularly from the flat surface. Keeping the rod perpendicular, tilt the board towards the sun until there is no shadow of the rod on the surface. When the board is in this position, it is receiving the maximum amount of insolation for that time of day. Use the protractor to measure the tilt angle of the surface. Record the tilt angle on the data sheet. After you have finished your measurements, answer the questions on the page following the data sheet.

DATA SHEET

Student Name: Location (city):

Season:

Early morning (Time =)

Optimal tilt angle = °

Mid-morning (Time =)

Optimal tilt angle = °

Noon

Optimal tilt angle = °

Solar noon (Time =)

Optimal tilt angle = °

Early afternoon (Time =)

Optimal tilt angle = °

Late afternoon (Time =)

Optimal tilt angle = °

Answer the following questions:

a. You are a solar system designer, and you must choose a single tilt angle for a collector. You want to maximize the amount of direct energy received by your collector during each day of the current season. What tilt angle would you choose? Explain your choice.

b. Would the tilt angle chosen above need to be adjusted during other seasons? Why or why not?

CONVERTING UNITS OF MEASUREMENT

You may encounter situations in which you will want to convert quantities of energy expressed in one unit of measurement to another unit of measurement. Recall that a British Thermal Unit (Btu) is the amount of heat required to raise the temperature of 1 pound of water by 1° F.

Perform the following conversions. Show your calculations. You may refer to the conversion factors in the previous reading assignment.

a. 220 Langleys = __________ Btu/ft^2

b. 721 KJ/m^2 = __________ Btu/ft^2

c. 73 Langleys/min = __________ Btu/ft^2/hr

d. 311 KJ/m^2/hr = __________ Btu/ft^2/hr

e. 110 w/m^2 = __________ Btu/ft^2/hr

SOLAR HEATING SYSTEMS CURRICULUM
UNIT LISTING

PHASE A: BASIC UNDERSTANDING

Unit	Task
SA-1	Explain the value of solar energy and principles of solar radiation.
SA-2	Describe basic solar system components and their functions.

PHASE B: DESIGN

Unit	Task
SB-1	Recommend non-solar energy conservation measures.
SB-2	Select passive solar approaches for new construction.
SB-3	Recommend collectors.
SB-4	Recommend and site the thermal storage unit.
SB-5	Recommend control devices.
SB-6	Recognize and describe modes of solar system operation.
SB-7	Calculate heat load for space or domestic hot water heating.
SB-8	Size solar system components.
SB-9	Perform a solar system economic analysis.
SB-10	Recommend a domestic hot water system.

PHASE C: INSTALLATION

Unit	Task
SC-1	Recommend correct thermal mass for direct gain system; fabricate and install modular wall units for passive solar.
SC-2	Schedule solar installation.
SC-3	Install a liquid storage tank.
SC-4	Site and mount collectors.
SC-5	Install liquid collectors and outside plumbing.
SC-6	Install inside plumbing for collector load side loops.
SC-7	Install controls and wiring.
SC-8	Start up system.

PHASE D MAINTENANCE

Unit	Task
SD-1	Maintain the solar system.
SD-2	Troubleshoot solar system problems

MAJOR BLOCK Solar Systems (Phase A: Basic Understanding) **NAME** ____________

TASK Describe basic solar system components & their functions.

UNIT SA-2 **TIME (est.)** ______ **(act.)** ______

OBJECTIVE(S) The student should be able to:

1) identify solar systems as active or passive systems, liquid or air systems
2) diagram and identify the major components of a solar space heating system, and their major functions
3) describe how heat energy circulates in different modes of operation
4) describe how cooling systems use solar energy.

START ➡ A-1 ▷ W-1 ▷ L-1 ▷ L-2 ▷ C-1 ▷ W-2 ▷ L-3 ▷ C-2 ▷

WRITTEN ASSIGNMENT(S)		**AUDIOVISUAL(S)**	
W-1	Assignment SA-2-1	A-1	Slide Set SA-2-1
W-2	Assignment SA-2-3	A-2	
W-3		A-3	
W-4		A-4	
W-5		A-5	
W-6		A-6	
W-7		A-7	

LABORATORY ASSIGNMENT(S)		**CHECKPOINT(S)**	
L-1	Assignment SA-2-2	C-1	Progress Check (written quiz)
L-2	Job Sheet SA-2-1	C-2	Test (written)
L-3	Assignment SA-2-4	C-3	
L-4		C-4	
L-5		C-5	
L-6		C-6	
L-7		C-7	
L-8		C-8	
L-9		C-9	

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ACTIVITY SEQUENCE SHEET

Activity	Flow Chart Number	Description of Activity
Slide Set SA-2-1	A-2	View Slide Set SA-2-1
Assignment SA-2-1	W-1	Read Fundamentals, page 1-1 to page 1-6 (up to "A heat pump for heating." Note that Figure 1-12(B) should be labeled, "Warm Water System?)
Assignment SA-2-2	L-1	Answer study exercises on Assignment Sheet SA-2-2
Job Sheet SA-2-1	L-2	Do activity described on Job Sheet SA-2-1
Progress Check	C-1	Written quiz
Assignment SA-2-3	W-2	Read Fundamentals, page 1-6 to page 1-10 (from "A heat pump for heating" up to "Economics")
Assignment SA-2-4	L-3	Answer study exercises on Assignment Sheet SA-2-4
Test	C-3	Written

SOLAR SYSTEMS: BASIC PRINCIPLES

a. How would you be able to tell if a solar system were active or passive?

b. Because solar energy is not always available, what two active system components must be included?

c. Describe one example of passive solar heating design.

d. What is the difference between the way in which flat plate and concentrating collectors gather solar energy? Which are used in residential installations? Why?

e. List the advantages and disadvantages of air versus liquid systems:

Air Systems

Advantages	Disadvantages
1.	1.
2.	2.
3.	3.

Liquid Systems

Advantages	Disadvantages
1.	1.
2.	2.
3.	3.

f. Make a schematic drawing of a solar space heating system. Label each of the major components. Below the drawing, list each major component and its function.

SOLAR SYSTEM ANALYSIS

Using the solar heating system (or model system) in your lab, name and identify the function of each of the major components of the system. In the space below, list the components and their functions. Describe the direction of heat flow when there is space heating from the collectors, space heating from the storage unit, or heating of the storage unit by the collectors. Label the system as an air versus liquid system, and the kind of storage unit.

SOLAR COOLING

a. Why are heat pumps sometimes included in solar systems?

b. In vapor-compression air conditioning systems, where can solar heat be used?

c. In absorption cooling systems, how can solar energy be used?

d. How can Solar Rankine-Cycle engines be used for cooling?

e. How can a rock storage unit be used to promote cooling?

f. Describe how a roof pond can be used for solar cooling. Could this same system be used for solar heating? Describe how.

SOLAR HEATING SYSTEMS CURRICULUM
UNIT LISTING

PHASE A: BASIC UNDERSTANDING

Unit	Task
SA-1	Explain the value of solar energy and principles of solar radiation.
SA-2	Describe basic solar system components and their functions.

PHASE B: DESIGN

Unit	Task
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SB-2	Select passive solar approaches for new construction.
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PHASE C: INSTALLATION

Unit	Task
SC-1	Recommend correct thermal mass for direct gain system; fabricate and install modular wall units for passive solar.
SC-2	Schedule solar installation.
SC-3	Install a liquid storage tank.
SC-4	Site and mount collectors.
SC-5	Install liquid collectors and outside plumbing.
SC-6	Install inside plumbing for collector load side loops.
SC-7	Install controls and wiring.
SC-8	Start up system.

PHASE D MAINTENANCE

Unit	Task
SD-1	Maintain the solar system.
SD-2	Troubleshoot solar system problems

MAJOR BLOCK Solar Systems (Phase B: Design) **NAME** ____________

TASK Recommend construction or remodeling techniques for energy efficiency

UNIT SB-1 **TIME (est.)** ________ **(act.)** ________

OBJECTIVE(S) The student will be able to:

Conduct an energy audit of a residence and make recommendations for changes to increase its energy efficiency.

START ➡

		W-1	L-1	W-2	L-2	W-3	L-3	W-4	L-4
W-5	C-1	C-2	C-3	L-5	C-4				

WRITTEN ASSIGNMENT(S)		**AUDIOVISUAL(S)**	
W-1	Information Sheet SB-1-1	A-1	
W-2	Information Sheet SB-1-2	A-2	
W-3	Information Sheet SB-1-3	A-3	
W-4	Information Sheet SB-1-4	A-4	
W-5	Information Sheet SB-1-5	A-5	
W-6		A-6	
W-7		A-7	

LABORATORY ASSIGNMENT(S)		**CHECKPOINT(S)**	
L-1	Job Sheet SB-1-1	C-1	Progress Check (written quiz)
L-2	Job Sheet SB-1-2	C-2	Progress Check (Instructor observation)
L-3	Assignment Sheet SB-1-1	C-3	Unit Test (Written)
L-4	Assignment Sheet SB-1-2	C-4	Unit Test (Practice)
L-5	Job Sheet SB-1-3	C-5	
L-6		C-6	
L-7		C-7	
L-8		C-8	
L-9		C-9	

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ACTIVITY SEQUENCE SHEET

Activity	Flow Chart Number	Description of Activity
Information Sheet SB-1-1	W-1	Read about tight construction.
Job Sheet SB-1-1	L-1	Check residence for tight construction.
Information Sheet SB-1-2	W-2	Read about Arkansas Plan construction.
Job Sheet SB-1-2	L-2	Investigate local use of Arkansas type construction.
Information Sheet SB-1-3	W-3	Read about caulking and weather stripping.
Assignment Sheet SB-1-1	L-3	Do study activities about caulking and weather stripping.
Information Sheet SB-1-4	W-4	Read about insulation.
Assignment Sheet SB-1-2	L-4	Do study activities about insulation.
Information Sheet SB-1-5	W-5	Read about energy efficient windows and doors.
Progress Check	C-1	Take written quiz.
Progress Check	C-2	Instructor Observation of all written work.
Unit Test (Part I)	C-3	Written: 30 points.
Job Sheet SB-1-3	L-5	Practice: Conduct energy audit. Make a tape recording of recommendations.
Unit Test (Part II)	C-4	Instructor observation of audit and recommendations tape: 70 points.

THE IMPORTANCE OF TIGHT CONSTRUCTION*

Air Infiltration

Energy conserving construction means tight construction. More insulation and better equipment can help, but the house must be tightly constructed in order for insulation to do its job effectively.

Air leakage in the house is called infiltration, and it costs the resident money. An average value for total infiltration in residential construction is one air change per hour! This means that under average conditions, in only one hour, all the air in the house leaves and is replaced by outside air - hot air in summer; cold air in winter. This causes higher heating and cooling bills, higher humidity during the summer, and dryer air during the winter. Infiltration or air leakage, may be up to 60% of the heating and cooling load of a well insulated house.

Where does all this air leak into and out of the house? The following table shows test results on a 1,780 sq. ft. house.

TABLE SB-1-1.1

TEST RESULTS: LOCATION OF LEAKS

Infiltration Area	Percent	Air Changes per Hour*
Soleplate	25	0.25
Wall Outlets	20	0.20
Duct System	14	0.14
Windows	12	0.12
Range Vent	5	0.05
Fireplace	5	0.05
Exterior Doors	5	0.05
Recessed Spot Light	5	0.05
Dryer Vent	3	0.03
Sliding Glass Door	2	0.02
Bath Vent	1	0.01
Other	3	0.03

Steps to Reduce Air Infiltration

Since infiltration (air leakage) is such a big part of the heating and cooling load of the average house, it is important to take steps during construction to reduce infiltration. The following steps will make the house much tighter. Notice that the steps are in the order of largest to smallest sources of loss; therefore, they are in order of most to least importance.

Steps to Reduce Air Leaks

1. Apply a bead of caulk between the soleplate and flooring or slab during installation. An alternate is to caulk the interior crack between the soleplate and flooring after it is secured. The soleplate is the cause of one-fourth of the air leakage (infiltration) in the house.
2. The second largest area is the electrical outlets on exterior walls. Caulk the wire and pipe holes where they penetrate the upper and lower wall plates, and pack the wall insulation behind the outlet box.
3. The duct system leaks can be reduced by taping the seams before applying duct insulation. Tape is still needed to contain the air in the duct, the insulation is not designed to do this.
4. Window infiltration is primarily leakage around the frame. The shim space between the rough opening and frame should be packed with insulation and covered with a vapor barrier.
5. The fireplace damper is the leakage point for a fireplace. Glass doors in front of the fireplace and exterior combustion air ducts can cut this loss.
6. Standard exterior doors can be replaced with foam core doors with superior weather-stripping.
7. Recessed spotlights and sliding glass doors should be avoided. They give outside air a free way in.

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*This material is taken from Craftsmen's Guide to Energy Conservation , Economic Development Division, Georgia Institute of Technology, 1978.

CHECKING FOR TIGHT CONSTRUCTION

MATERIALS:

Matches or smoke pills from toy electric train set

PROCEDURE:

Check the house or apartment you live in, or that of a friend, for air infiltration by carrying out the infiltration check for each of the following areas, where applicable:

- Soleplate
- Exterior Wall Outlets
- Duct Seams
- Window Frame
- Exterior Door Frames
- Sliding Glass Door and Frame
- Fireplace with Fire

INFILTRATION CHECK METHOD:

On a windy day, light a match or smoker from train set and blow it out immediately. Hold it close to the area to be checked. The smoke moves through the air in the direction of existing drafts. If the house has an attic fan, the check may be made (except for fireplace draw) by closing all windows and running the fan.

CONCLUSIONS:

Which of the areas listed above were applicable to the house you checked?

Which areas seemed to show the worst amount of air infiltration?

THE ARKANSAS PLAN

The Arkansas Power and Light Company has been building houses designed to be very energy efficient. They use less than half the energy of conventional housing. Some new ways of construction are used, as well as well-established ways of making houses energy efficient. Below are listed some of the essential parts of this method:

INSULATION

Insulation needs vary according to region. The following are requirements for Arkansas:

1. Sole Plate - Sill insulation or full bed of caulking installed around complete perimeter.

2. Concrete slab floor - 1½" rigid closed cell urethane foam perimeter insulation.

3. Crawl space floor - 6" fiberglass friction fit batts.

4. Ceiling - Two 6" fiberglass friction fit batts.

VAPOR BARRIERS

Exterior walls, ceiling and floors shall be provided with a vapor barrier, facing the heated side, with a transmission rate not exceeding one perm.

WINDOWS

Prime window should be caulked in place and the spaces around should be chinked and caulked. Wood frame two-pane windows or single pane windows with storm window are preferred. Any window facing the sun should be provided with a shading device during the cooling season.

EXTERIOR DOORS

Foam core metal doors with magnetic weather stripping are to be provided with weather-stripped thresholds with base flashing and caulking.

ATTIC SPACE

The attic should be ventilated by power roof ventilators, placed near the center of the roof ridge. Eave vents shall be evenly placed along the soffits. An inspection catwalk should be installed from the attic access opening to be extreme ends of the attic space.

WIRING AND PIPING

Wiring and piping should be installed so as to leave room for correct placement of insulation. In walls wiring should be allowed to lie on the sill plate by cutting notches in the base of wall studs before erection. In the attic, wiring should be attached to roof trusses at least 12" above the ceiling, so as to leave room for ceiling insulation.

WALL STUDS

Studs should be 2" x 6" spaced 24" on centers to permit all spaces to be fully insulated. Joints must occur centered on studs, be joined with a tie plate and each be anchored to the stud over which it rests. There is a reduction of about 41% in lumber. Plywood corner bracing should be used.

HEADERS

For houses up to 36' wide, and for openings up to 48" wide, headers shall be at least ½" thick, standard plywood, nailed with 8d common nails spaced 4" along edges, and glued with elastomeric exterior glue. Plywood will extend from the top of the opening to at least the center of the top plate, and horizontally to at least the second stud on either side of the opening. On larger windows, dual headers 2" x 6" or larger shall be installed to provide a void for insulation. Face grain of the plywood should be horizontal.

STRUCTURAL SUPPORT

All overhead loading must be placed directly on top of wall studs. Studs should be continuous from sill to rafters, with windows and doors placed to allow this, or additional support given.

DUCTS

Where possible, ducts are placed in the insulated living space by dropping the ceiling in passageways. Where they are not in heated space, ducts should be sealed with tape and insulated.

EQUIPMENT PLACEMENT

Heating and cooling equipment should be centrally located, with piping lengths reduced as much as possible. High EER (Energy Efficiency Rating) equipment should be used.

JOB SHEET SB-1-2

ARKANSAS PLAN CONSTRUCTION

Identify builders in your area who have used Arkansas Plan-type construction. Visit at least one site for this type construction. Find out:

- The features built in which are different from conventional construction.
- How these differences affect construction costs--materials and labor.
- What the experience in your area with respect to energy savings has been for this method.
- Write the answers to these questions in the space provided.

1. Arkansas Plan features utilized in this area, compared to conventional practice:

Arkansas Plan	Standard Practice

2. Arkansas Plan costs compared to standard practice:

	Labor Cost		Materials Cost	
Arkansas Plan Feature	Greater	Less	Greater	Less

3. Find out from the builder, or from the owner, any information you can about how effective this plan is in providing energy savings. Write what you found out here.

CAULKING AND WEATHERSTRIPPING

Too much movement of air in and out of a house can cause a very large part of the fuel bill. In a well-insulated house, the largest source of energy loss can be infiltration. Weatherstripping and caulking are good ways to eliminate drafts. They also make it easier to keep the house at an even temperature. They increase the comfort of the house.

Caulking is used to fill cracks at many places in a house. It can be used to fill in around frames of windows and doors, cracks in masonry, joints between masonry and wood, around flashing, and other spaces as well. Caulking should stick to both sides of the opening to be closed and yet remain flexible to permit movement between two unlike materials. Cracks between two different materials are called "moving joints," because different materials expand and contract at different rates. Caulking protects against heat loss and against entrance of moisture and insects. Table SB-1-3.1 describes several types of caulking.

Weatherstripping is a form of seal for door and window openings. This seal allows the door or window to shut tightly, yet also be opened. Table SB-1-3.2 describes several types of weatherstripping.

TABLE SB-1-3.1

CHARACTERISTICS OF DIFFERENT TYPES OF CAULKING*

Type of Caulk	Advantages/Application	Problems/Solutions	Cost
Oil Base.	Adheres to most surfaces--prime porous surfaces.	Not for use on moving joints. As oil dries out, caulk shrinks; 1 to 7 year life--prolong life by painting after drying.	Low.
Latex Base.	Long life up to 10 years (some are guaranteed for 20 years). Adheres well to most surfaces--prime or paint metal and porous surfaces. Dries quickly--can be painted in 15-30 minutes--accepts most paints.	Shrinks some--apply a big bead of caulk and use it to fill only narrow cracks.	Medium.
Butyl Rubber.	Should last up to 10 years if properly applied. Can be applied indoors or out, on metal or masonry. Can be painted with any type of paint after curing for a week.	Shrinks a little--apply a wide bead and cover only small cracks.	Medium.
Ployvinyl Acetate (PVA).		Loses flexibility when it dries--use only for small holes indoors.	High.
Silicone Seal.	Excellent sealant--can last for at least 20 years. Adheres to just about any surface and shrinks very little. Ideal for moving joints--stretches up to 7 times its cured width.	Usually cannot be painted--some come in various colors.	High.

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*From Providing for Energy Efficiency in Homes and Small Buildings. AAVIM. Athens, Georgia, 30602.

TABLE SB-1-3.1 (CONC'D)

CHARACTERISTICS OF DIFFERENT TYPES OF CAULKING*

Type of Caulk	Advantages/Application	Problems/Solutions	Cost
Nitril Rubber.	Long lasting--15 to 20 years. Extremely good for high moisture areas. Adheres well to metal, masonry and other unprimed surfaces. Can be painted after 10 to 20 minutes --painting is not necessary.	Shrinks considerably--do not use on moving joints or cracks over 1/8". Does not adhere well to painted materials.	High
Neoprene Rubber	15 to 20 year life span. Especially good for use on concrete walls and foundations. Moderate shrinkage--can be used on moving joints less than 1/4 inch. Accepts paint but not needed.	Dries tack-free in about 1 hour but takes from 1 to 2 months to cure fully. Ordinary solvents are of no help in removing neoprene rubber--use either MEK or bolulene with caution.	High
Polysulfide	Over 20-year life on moving joints. Thoroughly shrink resistant.	CAUTION: Toxic until cured--up to 3 full days before tack-free. Special primer required on porous surfaces such as wood or masonry. Toluline and MEK will clean away excess--follow directions on label.	
Hypalon	Excellent caulk made to last up to 20 years. It can be used on moving joints. Will adhere to any surface. Easy to work with.	Not in general distribution. Requires priming before use on porous materials --check label.	High
Polyurethane	Can be used on moving joints. Will last up to 20 years. Will adhere to any surface, no priming needed. Easily applied.	Requires 24 hours to become tack-free and up to two weeks to cure. Not in many retail outlets. Use paint thinner or acetone for cleanup.	Low
Rope Caulk	Can be used on wide gaps. Does not dry out. Does not shrink. Easily applied--seasonal use is possible on storm windows.	Considered only a temporary solution to air leaks. Cannot be painted.	Low

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*From Providing for Energy Efficiency in Homes and Small Buildings. AAVIM. Athens, Georgia, 30602.

TABLE SB-1-3.2

CHARACTERISTICS OF DIFFERENT TYPES OF WEATHERSTRIPPING*

Type of Weatherstripping	Material/Form	Advantages	Problems	Cost
Pressure-Sentive, Adhesive-Backed Foam	Polyurethane foam with vinyl cover in roll OR closed-cell vinyl foam.	Easy to install. Cushioning effect--noise reduction in closing. Good seal.	Avoid painting--causes loss of resiliency. 1-3 yr life--not durable. More effective on doors.	Low to Medium.
Metal Spring	Bronze, copper, stainless steel, or aluminum.	Excellent seal. Very durable.	Requires patience for installation.	Medium.
Self-Sticking	V-shaped or single roll strip.	Easy to install.		
Felt or Self-Sticking	Variety of widths and thicknesses in a roll.	Easy to install. Various colors.	Variable life-may stick to door finishes.	Low.
Serrated Metal	Felt or vinyl-backed metal roll.	Easy to install.		Medium.
Tubular Gasket (rolled vinyl)	Flexible vinyl in tubular form with or without metal backing.	White or gray. Easy to install. Very good, durable seal.	Cannot be painted or it will lose flexibility.	High.
Foam-filled Tubular Gasket				

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*From Providing for Energy Efficiency in Homes and Small Buildings. AAVIM. Athens, Georgia, 30602.

TABLE SB-1-3.2 (CONCL'D)

CHARACTERISTICS OF DIFFERENT TYPES OF WEATHERSTRIPPING*

Type of Weatherstripping	Material/Form	Advantages	Problems	Cost
Interlocking Metal	Two interlocking pieces--strip.	Tight seal. Best available for doors.	Difficult to install due to alignment and cutting. Maintenance requires straightening of bent pieces.	High.
Casement Window Gasket	Vinyl roll.	Easy to install--slip on lip of window.	Gray only.	Medium.
Jalousie Gaskets	Clear vinyl. U-shaped track.	Easy to install--slip on.		Medium.
Door Sweeps	Wood and felt or wood and foam or metal and vinyl strips.	Easy to install. Effective seal against drafts.	Must clear carpet.	Medium.
Thresholds	Vinyl insert in metal base strip OR two-piece interlocking strip.	Generally best seal for exterior doors.	Often requires removal of old threshold or cutting of door.	High.

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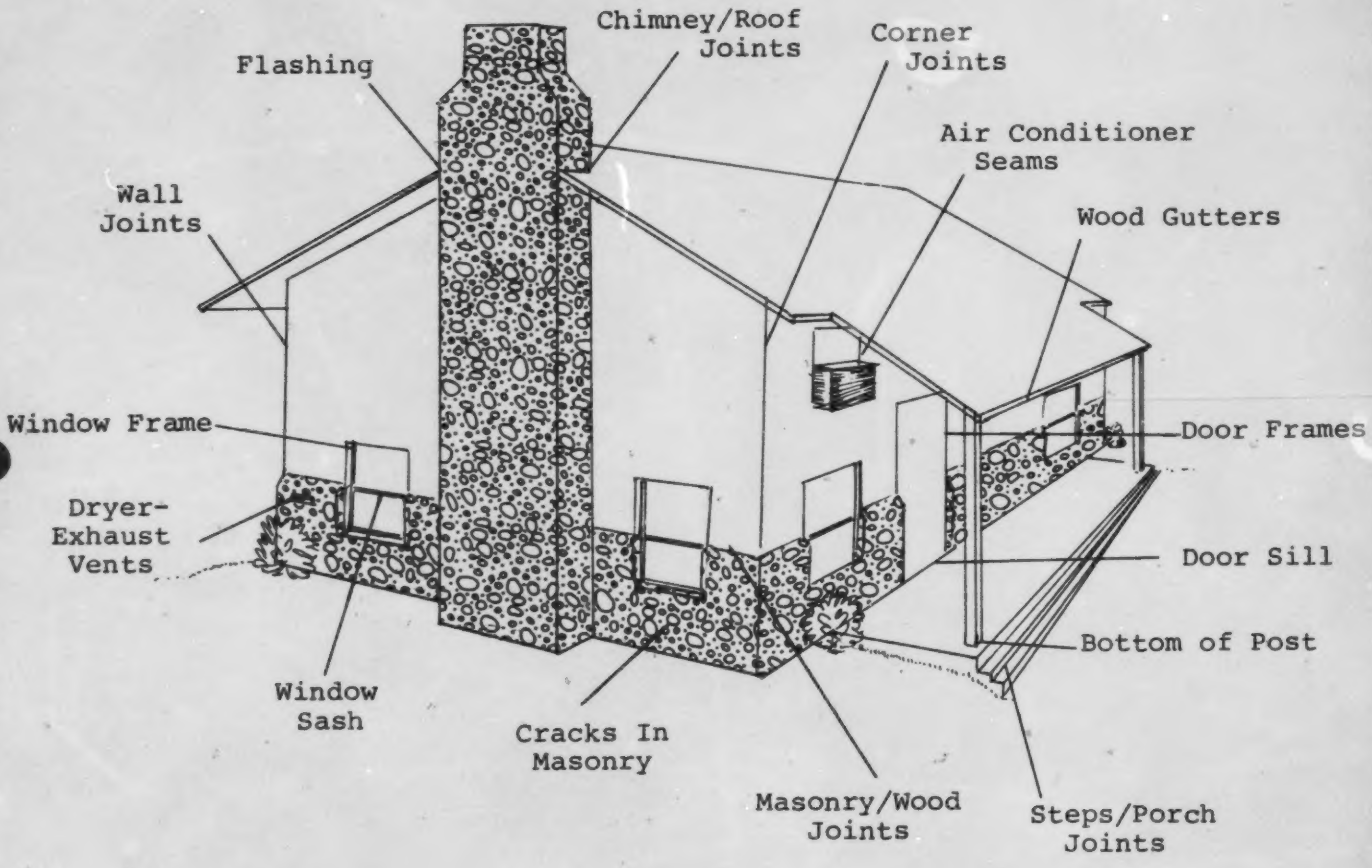
*From Providing for Energy Efficiency in Homes and Small Buildings. AAVIM. Athens, Georgia, 30602.

WEATHERSTRIPPING AND CAULKING

1. For the following diagram, place a "C" at each location where caulking may be necessary. Place a "W" where weatherstripping is needed. Place an "O" where neither is needed.


Chimney/Roof Joints
Flashing
Corner Joints
Air Conditioner Seams
Wall Joints
Wood Gutters
Window Frame
Door Frames
Dryer-Exhaust Vents
Door Sill
Bottom of Post
Window Sash
Cracks In Masonry
Masonry/Wood Joints
Steps/Porch Joints

2. The purpose of weatherstripping and caulking is to

____.

3. Use a hair dryer and check the exterior doors in your residence for the effectiveness of existing weatherstripping. Does any of this weatherstripping need replacement?

4. Check the prices at your local supplier for the types of weatherstripping listed in Table SB-1-3.2 on Information Sheet SB-1-3. Enter the price you locate on that table. What are the two best choices in your area? Why did you select these two, rather than the others on the list?

5. Repeat question (4) for caulking listed in Table SB-1-3.1.

INSULATION*

Insulation is material that fills in air spaces between the inside and outside of a house. Insulation slows down heat flow. Since warm air rises, the best place to install insulation is in the ceiling. The loss of cool air in the summer and the loss of warm air in the winter can be reduced by insulating:

Ceiling covered by unheated space
Exterior walls
Floor over unheated space
Ductwork in unheated space
Waterheaters

There are two benefits of adding thermal insulation:

1. Money and energy are saved, less heat is lost in the winter and less air conditioning is needed in summer.

2. More comfort is provided. Walls, ceilings and floors will be closer to the temperature of the air in the room, rather than to the conditions outside. If walls are cold, even when the air is warm in a room, people feel cold. They lose heat by radiation to the cold wall surface. Then even when the air is warm people are likely to turn the heat up.

Insulation is rated by its R(heat resistance value). The higher the R value, per inch of thickness, the better the insulation. To get the R-value for a certain type of wall, you figure out the R-value for each part of the wall, from a table like Table SB-1-4.1, and add the R-values for all parts.

There are four basic insulation materials commonly used in new construction:

1. Fiberglass is the best all around insulation for most purposes. While it is fire resistant, it should be noted that the vapor barrier usually attached to it is not.

2. Rigid foams are now in use, primarily for wall sheathing. They are more expensive than fiberglass per R (heat resistance) value, but they are used for purposes for which fiberglass is not suited. The polystyrene and urethane foams are the most flammable, and must be covered with sheet rock to pass code. The isocynauate types are the most fire resistant, but require poly vapor barriers.

3. Cellulose insulation is good for attics, and some insulation installers can spray it into the wall cavity with a binder to keep it in place. Fire resistance of this material is dependent on chemical treatment. Two specifications which certify that cellulose is fire resistant are:

Federal Specification HH-I-515D and Underwriters Laboratories Classification listing Type I. These specifications are pending, and may change. This materials should be kept 3" away from heat sources, such as recessed spot lights.

4. Urea formaldehyde 'wet foam' insulation has made little penetration in the new home market. The product is relatively new and is used only in walls. The possibility of shrinkage of the materials, formaldehyde odor, and high price are its drawbacks. Foams also burn producing smoke and poisonous gases such as carbon monoxide. The properties of foam depend on the specific type and on the method of installation.

Vapor barriers reduce the rate of flow of water vapor. They are used on the wall, floor and ceilings of residential construction to prevent water vapor from entering the insulation in large enough quantities to cause condensation. They must be installed facing the heated area. When water vapor touches a cold surface below the dewpoint temperature of air, the water vapor condenses to liquid water and wets the insulation. This causes a loss of insulating capability, and possible rotting of the wood and peeling of exterior paint. Vapor barriers are especially important in kitchen and bathroom areas where high concentrations of water vapor exist. Extra care should be taken in these areas to provide a continuous and undamaged vapor barrier. Low permeability paint such as high gloss enamel is useful here. Vapor barriers are also installed on top of the earth in crawlspace of a house to keep the crawlspace dry. Finally, vapor barriers help produce a better living environment in the house by keeping it dryer in the summer, and maintaining higher humidities during the winter.

Ventilation will remove water vapor before it gets a change to condense in the insulation. Ventilation also reduces the collection of moisture on beams and rafters of a house, and is usually provided for in the attic of a house.

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*This material is taken from Craftsmen's Guide to Energy Conservation, Economic Development Division, Georgia Institute of Technology, 1978.

TABLE SB-1-4.1

COMPARISONS OF INSULATION QUALITIES**

Insulation Materials	Form	Approx.* R-Value Per Inch Thickness	Fire Resistant	Vermin Proof	Insect Proof	Moisture Resistant	Other Problems
Insulation Sheathing	Board	2.0	No	-	-	Little	
Vermiculite Perlite	Loose-fill	2.1 2.7	Yes	Yes	Yes	No	Settling.
Fiberglass	Blanket Batt Loose-fill	3.0 to 3.5	Yes	Yes	Yes	No	Skin irritant when handled; develops odor when damp.
Rock Wood (Mineral Wool)	Blanket Batt Loose-fill	3.0 to 3.3	Yes	Yes	Yes		Skin irritant when handled.
Cellulose Fiber	Loose-fill	3.7	When treated	When treated	When treated	Somewhat	
Polystyrene (styrofoam)	Board	Blue 5.5 White 4.0	No	Yes	Yes	Yes	Punctures easily.
Urea Formaldehyde	Foam, Blown or Sprayed on	4.0	No	Yes	Yes	Yes	Some shrinkage--up to 3%.
Polyurethane	Foam, Blown or Board	6.5	No	Yes	Yes	Yes	
Still air space	Between studs	.3	Yes	Yes	Yes	Yes	

*R-Values vary with manufacturers.

**From Providing for Energy Efficiency in Homes and Small Buildings. AAVIM. Athens, Georgia, 30602.

TABLE SB-1-4.2

GENERAL RECOMMENDATIONS FOR ENERGY EFFICIENCY IN RESIDENCES (HUD, 1978)**

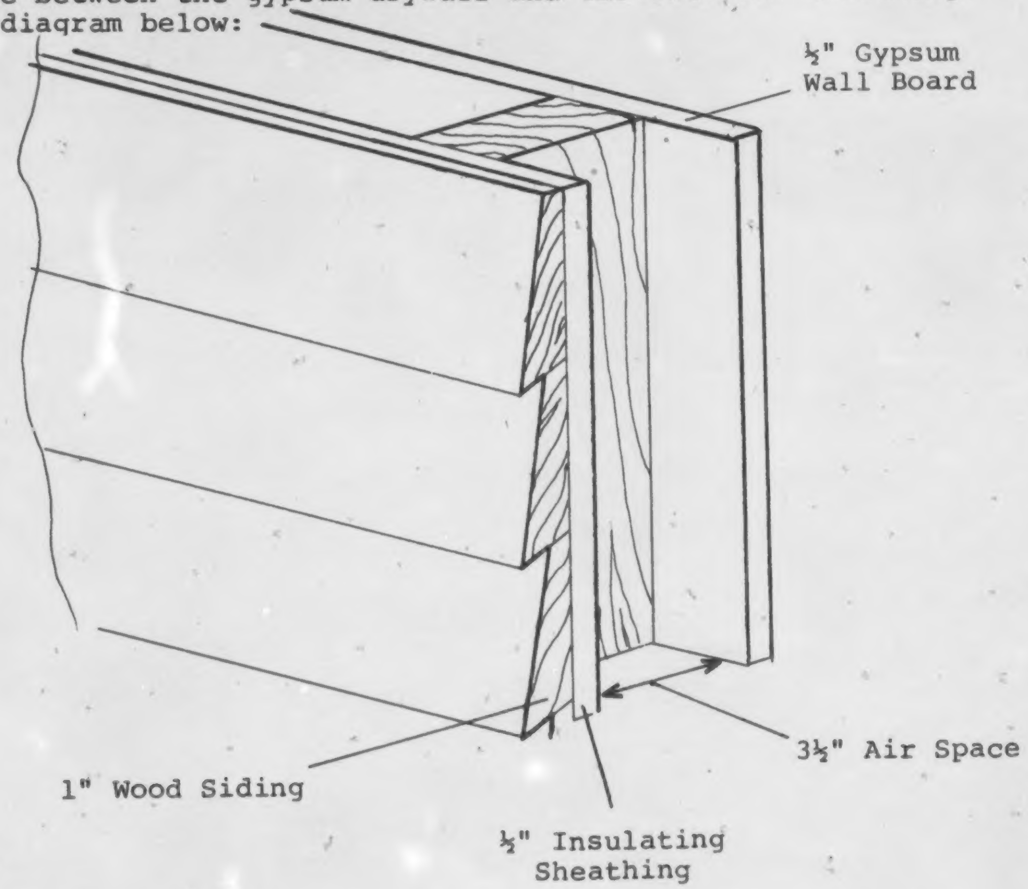
Winter Degree Days	Heating Fuel	Ceilings	Walls	Floors Over Unheated Spaces	Foundation Walls of Heated Spaces	Layers of Glazing: Windows and Glass Doors	Storm Door or Thermal Door
0 - 1001	Electricity	R19	R11[a]	R11	-	1	No
	Fossil Fuel or Heat Pump	R19	R11[a]	-	-	1	No
1001 - 2500	Electricity	R22	R13[a]	R13	-	2	No
	Fossil Fuel or Heat Pump	R19	R11[a]	-	-	1	No
2501 - 4500	Electricity	R30	R13[a]	R19	R7	2	No[c]
	Fossil Fuel or Heat Pump	R22	R13[a]	R13	R7	1	No[c]
4501 - 7000	Electricity	R30	R13	R19	R7	3[b]	Yes
	Fossil Fuel or Heat Pump	R30	R13	R13	R7	2[b]	No[c]
7000 or more	Electricity	R38	R13	R19	R7	3[b]	Yes
	Fossil Fuel or Heat Pump	R30	R13	R19	R7	2[b]	Yes

[a] Recommended only when wall covering is removed and an adequate vapor barrier is installed.
[b] Insulating frames should also be provided if replacement sashes are installed.
[c] Storm or thermal door is recommended if the primary door is hollowcore or over 25% glass.

** From Providing for Energy Efficiency in Homes and Small Buildings. AAVIM. Athens, Georgia, 30602.

INSULATION

1. Suppose an existing house has exterior walls constructed of common brick, on a standard 2" x 4" stud wall, with ½" of drywall in the interior. Such construction leaves a 3½" air space between the gypsum drywall and the exterior sheathing. See diagram below:


½" Gypsum Wall Board
3½" Air Space
1" Wood Siding
½" Insulating Sheathing

Such a wall may have an R-value of about 4.0. Using Table SB-1-4.1 in Information Sheet SB-1-4 (Insulation), determine the highest R_{TOTAL} that can be attained by filling the 3½" air space with insulation.

2. Visit a local supplier and fill in the "Cost" column in Table SB-1-4.1 in Information Sheet SB-1-4. Verify the R-values in the table for the brands available at this supplier.

3. What is the purpose of a vapor barrier?

4. Which side of the insulation should the vapor barrier be?

5. In the following list, place a letter "I" beside locations which should be insulated.

   Interior walls
   Exterior walls
   Ceilings exposed to heated rooms
   Ceilings exposed to unheated attics
   Living area ceiling directly covered by roofs
   Floors exposed to unheated areas
   All hardwood floors
   Crawl space walls
   Band joist
   Basement walls

6. Use the Table SB-1-4.2, and determine how much insulation should be used in floors and ceilings in this area.

WINDOWS AND DOORS *

The window is both hero and villain in energy conservation. Windows admit natural sunlight, fresh air, and ventilation. They also lose heat during the winter and gain heat during the summer. Obviously, a compromise is needed. Proper window design incorporates the following rules.

1. Minimize the total amount of glass area, keeping it just above minimum code requirement.
2. Use walls to reflect light and place windows close to sidewalls to get the most reflectance.
3. Eliminate or minimize use of glass on the west side to reduce solar heat gain during the summer.
4. Minimize use of glass on the north side, to reduce heat loss in the winter.
5. Maximize use of glass on the south side and use a properly designed overhang to shade the glass during the summer and allow the sun to enter during the winter. More winter sun than summer sun shines in south-facing windows.
6. Use high quality windows with low infiltration rates, install storm windows or double glazing.

Large expanses of glass are a thing of the past, unless specially designed on a passive solar collector system on the south side of a house. A single pane window on the north side of a house loses about 20 times more heat per square foot than a well insulated wall. It can be said that people who live in glass houses - shouldn't. The cost of heating and cooling them will become prohibitive in the future.

Winter Heat Loss

U values are commonly used to express overall conduction heat loss for windows. The U value is the reciprocal of the R factor. (A window with a U value of 0.5 has an R value of 1/0.5 = 2.0). A single pane window has a U value of 1.13, add a storm window, and the U value is 0.64, or 44% less heat loss. Double glazing has a U value of 0.42, 63% less heat loss than single pane. Triple glazing is not economic in Georgia at this time, but may prove feasible in the future, especially on all electric homes.

Certain types of windows are less energy efficient than others. Jalousie windows that crank open and shut are very difficult to seal. Metal-frame windows transmit about 20% more heat than wood-frame windows.

Summer Heat Gain

Solar heat gain is a large portion of the air conditioning load. It is worth comparing the heat gain of various window types and placements, using a single pane, east or west facing window as the basis. The table shows that unshaded east or west glass produces the highest air conditioning load. West glass is the worst orientation, as the solar gain through the window occurs at the hottest time of the day.

Exterior shading (shade screen, awnings, porches, trees) is the most effective way to control solar heat gain which causes high air conditioning loads. Placing the garage or carport on the west side of the house and eliminating the glass on this side is the most effective way to prevent the problem before the house is built.

TABLE SB-1-5.1

WINDOW HEAT GAIN COMPARISON

	Percent Reduction in Window Heat Gain
Single pane, no shade, facing east or west	0
Single pane, no shade, facing south	47
Single pane, no shade, facing north	65
Single pane, with white roller shades, facing west	24
Single pane, with full shade, all directions	71
Double pane, with full shade, all directions	82

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*This material is taken from Homebuilder's Guide to Energy Conservation, Georgia Institute of Technology, 1979.

JOB SHEET SB-1-3
UNIT TEST
(PRACTICE PORTION)

Obtain this Job Sheet from your Instructor after you have passed the written portion of the Unit Test. This exercise counts 70 percent of your grade for this Unit.

SOLAR HEATING SYSTEMS CURRICULUM
UNIT LISTING

PHASE A: BASIC UNDERSTANDING

Unit	Task
SA-1	Explain the value of solar energy and principles of solar radiation.
SA-2	Describe basic solar system components and their functions.

PHASE B: DESIGN

Unit	Task
SB-1	Recommend non-solar energy conservation measures.
SB-2	Select passive solar approaches for new construction.
SB-3	Recommend collectors.
SB-4	Recommend and site the thermal storage unit.
SB-5	Recommend control devices.
SB-6	Recognize and describe modes of solar system operation.
SB-7	Calculate heat load for space or domestic hot water heating.
SB-8	Size solar system components.
SB-9	Perform a solar system economic analysis.
SB-10	Recommend a domestic hot water system.

PHASE C: INSTALLATION

Unit	Task
SC-1	Recommend correct thermal mass for direct gain system; fabricate and install modular wall units for passive solar.
SC-2	Schedule solar installation.
SC-3	Install a liquid storage tank.
SC-4	Site and mount collectors.
SC-5	Install liquid collectors and outside plumbing.
SC-6	Install inside plumbing for collector load side loops.
SC-7	Install controls and wiring.
SC-8	Start up system.

PHASE D MAINTENANCE

Unit	Task
SD-1	Maintain the solar system.
SD-2	Troubleshoot solar system problems

MAJOR BLOCK Solar Systems (Phase B, Design) **NAME** ____________

TASK Select Passive Solar Approaches for New Construction

UNIT SB-2 **TIME** (est.) ______ (act.) ______

OBJECTIVE(S) The student will be able to:

(1) Make specific recommendations for designing in passive heating/cooling capability to new construction.

(2) Explain six major design types of passive solar.

(3) Explain expected heat flow patterns in the six types for winter day, winter night, summer day, summer night.

START ➔ A-1 ▷ W-1 ▷ L-1 ▷ A-2 ▷ C-1 ▷ L-2 ▷ W-2 ▷ A-3 ▷ L-3 ▷ C-2 ▷ W-3 ▷ A-4 ▷ L-4 ▷ W-4 ▷ A-5 ▷ L-5 ▷ C-3 ▷ L-6 ▷ C-4 ▷ C-5 ▷

WRITTEN ASSIGNMENT(S)

W-1 Information Sheet SB-2-1
W-2 Information Sheet SB-2-2
W-3 Assignment SB-2-4
W-4 Assignment SB-2-6
W-5 ____________
W-6 ____________
W-7 ____________

LABORATORY ASSIGNMENT(S)

L-1 Assignment SB-2-1
L-2 Assignment SB-2-2
L-3 Assignment SB-2-3
L-4 Assignment SB-2-5
L-5 Assignment SB-2-7
L-6 Job Sheet SB-2-1
L-7 ____________
L-8 ____________
L-9 ____________

AUDIOVISUAL(S)

A-1 Slide Set SB-2-1
A-2 Slide Set SB-2-2
A-3 Slide Set SB-2-3
A-4 Slide Set SB-2-4
A-5 Slide Set SB-2-5
A-6 ____________
A-7 ____________

CHECKPOINT(S)

C-1 Progress Check
C-2 Progress Check
C-3 Observation
C-4 Test
C-5 Test
C-6 ____________
C-7 ____________
C-8 ____________
C-9 ____________

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Superintendent of Schools
1979

No person shall, on the basis of sex, race, national origin or handicap, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity under the direction of the local education agency.

ACTIVITY SEQUENCE SHEET

Activity	Flow Chart Number	Description of Activity
Slide Set SB-2-1	A-1	View slide set SB-2-1 (Introduction to Passive by NMSEA A.)
Information Sheet SB-2-1	W-1	Read Information Sheet SB-2-1 on Passive Systems
Assignment SB-2-1	L-1	Do study exercises on Assignment Sheet SB-2-1
Slide Set SB-2-2	A-2	View slide set SB-2-2
Assignment SB-2-2	L-2	Do study exercises on Assignment Sheet SB-2-2
Progress Check	C-1	Review your answers to Assignment Sheet SB-2-1, 2 with the instructor.
Information Sheet SB-2-2	W-2	Read Information Sheet SB-2-2 on Design Considerations
Slide Set SB-2-3	A-3	View Slide Set SB-2-3 N.M.E.A. B,C
Assignment SB-2-3	L-3	Do study exercises on Assignment Sheet SB-2-3
Progress Check	C-2	Quiz over Activities to this point
Assignment SB-2-4	W-3	Read Survey, pp 25-27, 69-70, 89-90
Slide Set SB-2-4	A-4	View N.M.S.E.A. Slide Set D
Assignment SB-2-5	L-4	Do study exercises on Assignment Sheet SB-2-5
Assignment SB-2-6	W-4	Read Survey, pp 109-110, 121-122, 157-158
Slide Set SB-2-5	A-5	View N.M.S.E.A. Slide Set E,F
Assignment SB-2-7	L-5	Do study exercises on Assignment Sheet SB-2-7

Observation	C-3	Go over your answers to Assignment Sheet, L-4,5, with your instructor and any other students who have finished theirs.
Job Sheet SB-2-1	L-6	Carry out instructions on Job Sheet SB-2-1. Repeat until you are satisfied with the tape you make.
Test Part One	C-4	Play the tape from L-6 for your instructor for grading (10%)
Test Part Two	C-5	Written test for grading. (90%)

PASSIVE SOLAR DESIGN

Definitions

Passive solar design approaches use the energy of the sun and principles of natural heat flow to heat and cool living spaces and to heat water in buildings. Very few or no mechanical or electrical aids are used in passive systems. Instead, the structure of the building itself--its walls, roof, windows, and vents--is designed to do the job of heating air or water.

Passive approaches are increasingly important in the face of great political instability in OPEC nations and in the face of sharply rising costs of all forms of energy. Proper orientation and good construction techniques can produce houses that use only a fraction of the non-solar energy required to heat conventional houses.

In this unit you will learn about six major kinds of passive designs. They may be used alone or in combination with other active solar systems and with conventional systems.

- Passive solar systems use natural energy flows for transfer of thermal energy into, out of, and through a building.
- Hybrid solar systems are passive solar systems combined with mechanical or electrical aids to improve energy transfer and/or to add an additional level of control.

Design Types

There are three main types of passive systems. These are different from each other with respect to the relation between the sunlight and the space to be heated.

Direct gain systems allow sunlight from the south to enter the space to be heated directly. Indirect gain systems locate thermal storage such as masonry or water between sunlight entering through south-facing glass or plastic and the space to be heated. Isolated gain systems permit sunlight to be both collected and stored as heat in areas separate from the space to be heated. On the next page are diagrams of examples of each type.

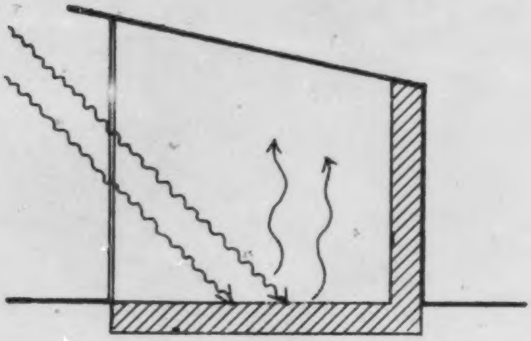


Figure 1. Direct Gain

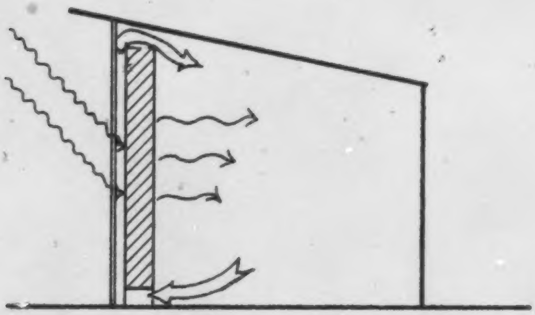
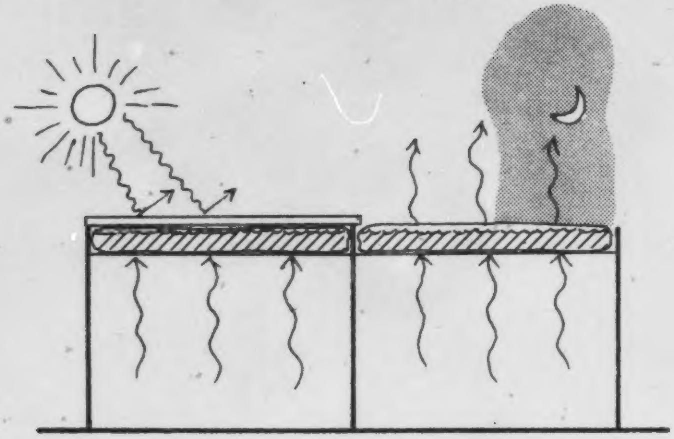
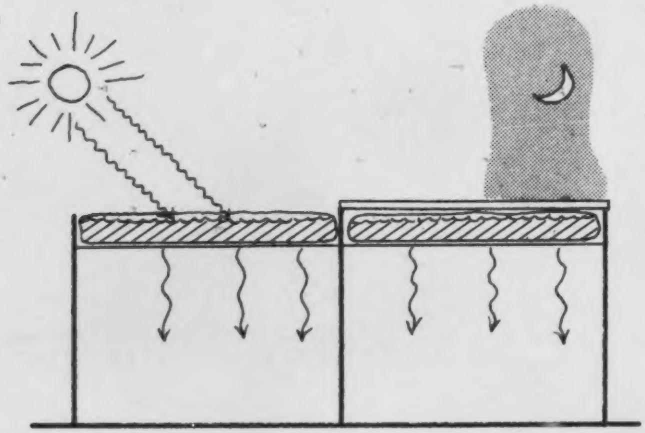


Figure 2. Indirect Gain: Thermal Storage Wall



Summer Cooling



Winter Heating

Figure 3. Indirect Gain: Thermal Storage Roofs: Summer & Winter Operation

Source: U. S. Department of Energy, D.O.E./CS-0011, UC-59a, b, c; August, 1978.

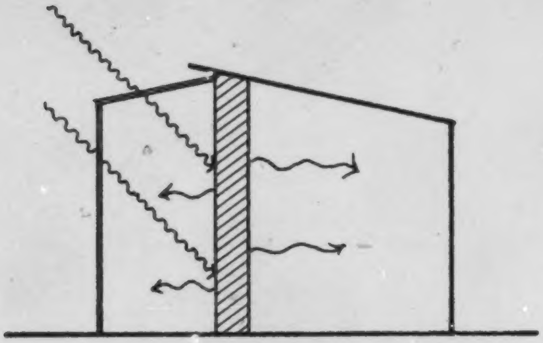


Figure 4. Isolated Gain: Solar Greenhouse

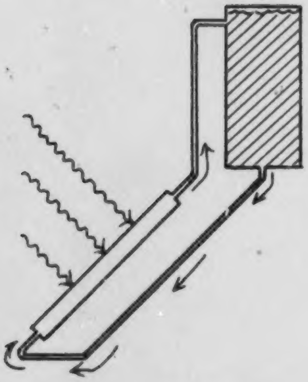


Figure 5. Isolated Gain: Convective Loop: Water Heating

68

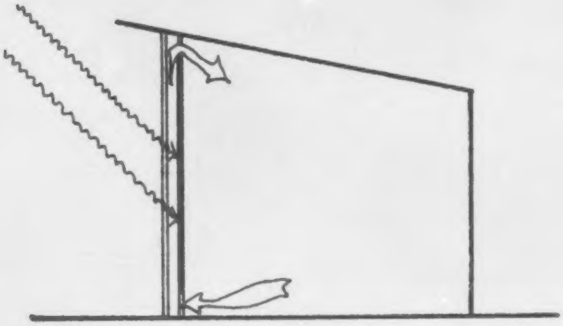


Figure 6. Isolated Gain: A Thermosiphoning Air Collector

1. The difference between passive, hybrid, and active systems depends on whether thermal energy flow is natural or forced. Label the following rows (a,b,c, & d) with the correct word--active, passive, or hybrid.

(a)____________System

	Thermal Energy	Flows
	Natural	Forced
Collector to Storage	X	
Storage to Space	X	

(b)___________System

	Natural	Forced
Collector to Storage	X	
Storage to Space		X

(c)__________System

	Natural	Forced
Collector to Storage		X
Storage to Space	X	

(d)_________System

	Natural	Forced
Collector to Storage		X
Storage to Space		X

2. Looking at the direct gain diagram(Figure 1) on Information Sheet SB-2-1, answer the following questions.

   (a) Which way should the glass in a direct gain system be oriented?

   (b) How can excess heat gain in the summer be prevented?

   (c) How can heat loss at night be reduced, in this direct gain system?

   (d) What is one disadvantage to use of direct gain as the only means to heat a space?

3. Looking at the indirect gain diagram: Thermal Storage Wall (Figure 2) from Information Sheet SB-2-1, answer the following questions:

   (a) Why are there openings in the top and bottom of the thermal storage wall?

   (b) What could be done to prevent unwanted heat loss at night?

   (c) Can you think of three ways to reduce summer heat gain in this system?

4. Thermal storage roof ponds can provide both heating and cooling. The diagram on Information Sheet SB-2-1 (Figure 3) suggests why. Answer the following questions:

   (a) The dotted material in the sketch is moveable insulation. Why is it essential?

   (b) What can be done to prevent loss of water by evaporation?

(c) Is energy transfer in this system more by radiation or by convection?

5. The solar greenhouse is one passive approach that can be added to existing buildings. Look at Figure 4 in Information Sheet SB-2-1 to answer these questions.
   (a) Where might heat be stored in this design?

   (b) Can you think of some ways to control heat flow in solar greenhouse or "sunspace" type building?

   (c) The convective loop water heater and the thermosiphoning air collector operate on the same principles. Looking at the diagrams, Figure 5 & Figure 6, tell what they have in common.

   (d) From what you've seen so far, what are the main advantages of passive solar design?

ASSIGNMENT SHEET SB-2-2

1. Label the systems in the sketches at the end of this section with respect to their solar systems. Select the labels from the following terms:

General Design

Direct Gain

Indirect Gain

Isolated Gain

Design Type

Direct Gain

Mass Trombe

Water Trombe

Air Thermosiphon

Water Thermosiphon

Sun Space

Roof Pond

Component Function

Heat Storage

Solar Energy Trap

Heat Transfer

Heat Barrier (Insulation)

Control (of heat flow)

Type of Heat Flow

Summer Day

Winter Day

Summer Night

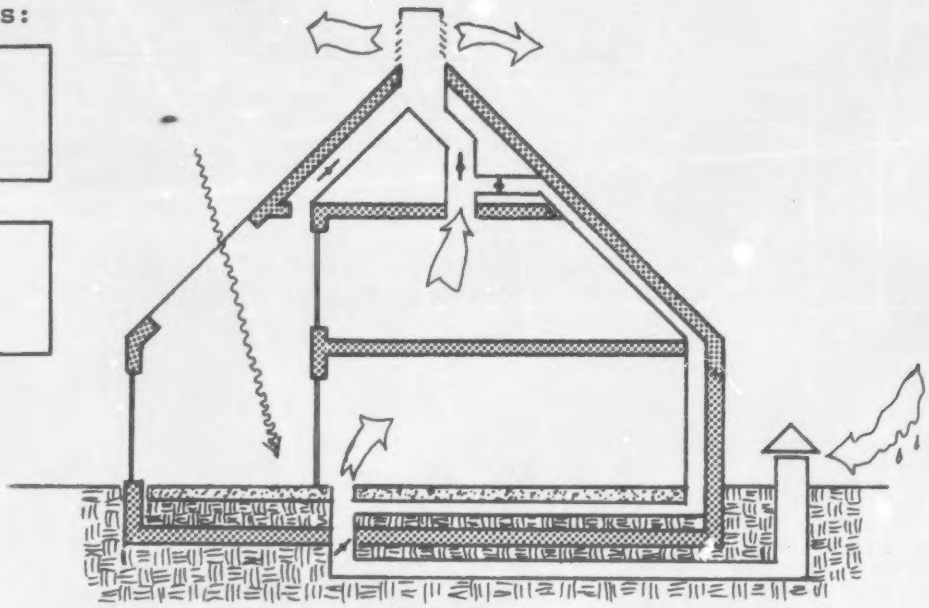
Winter Night

General Design:

Design Type:

Heat Flow Type:

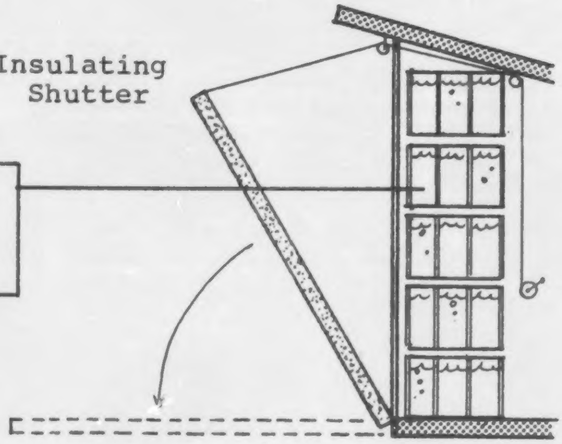
Functions:



General Design:

Design Type:

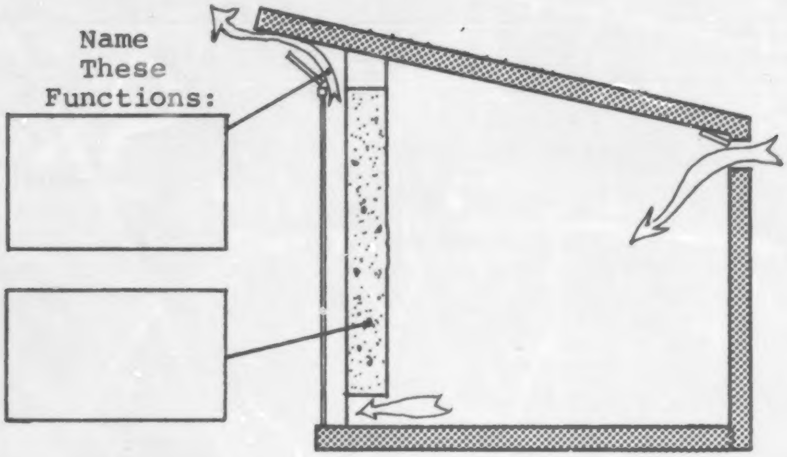
Function:


Insulating
Shutter

General Design:

Design Type:

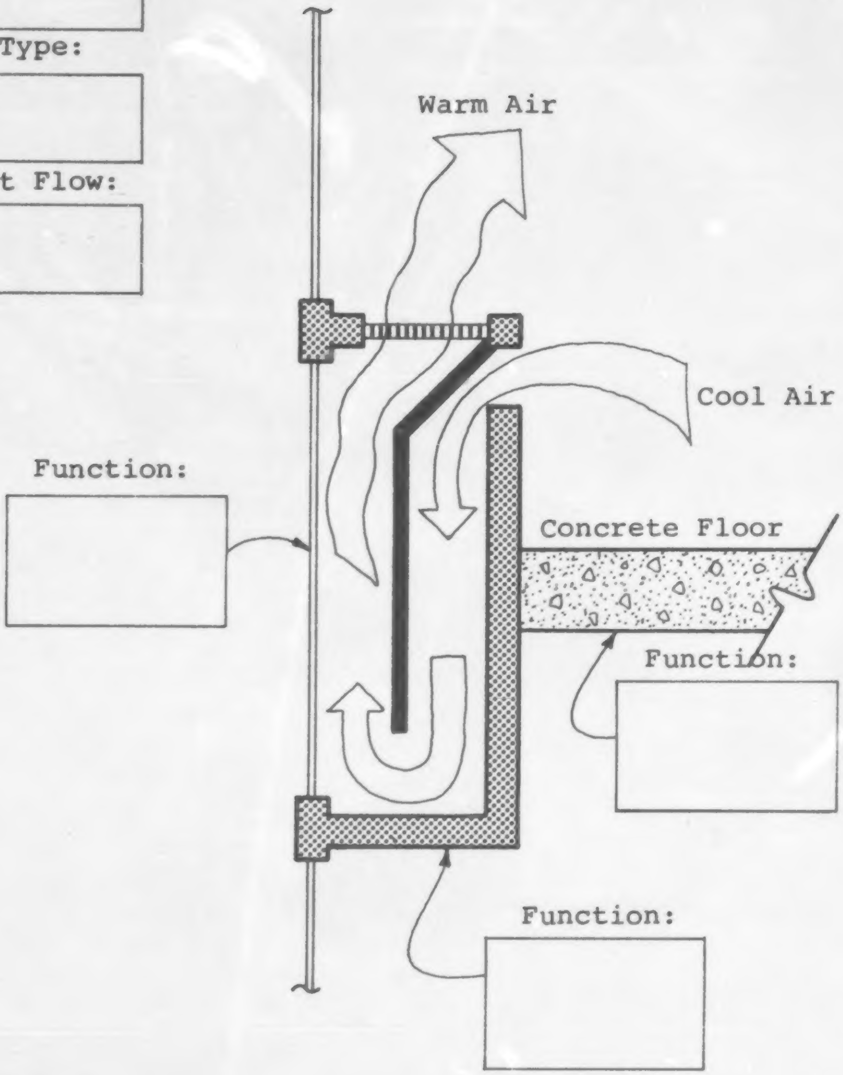
Type of Heat Flow:


Name
These
Functions:

General Design

Design Type:

Type of Heat Flow:

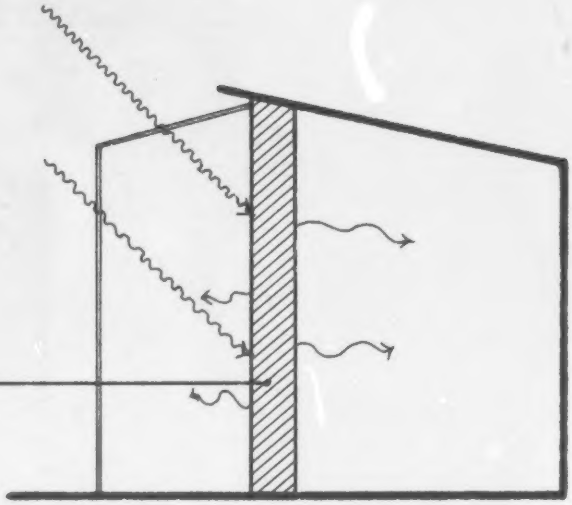

Warm Air
Cool Air
Function:
Concrete Floor
Function:
Function:

General Design:

Design Type:

Type of Heat Flow:

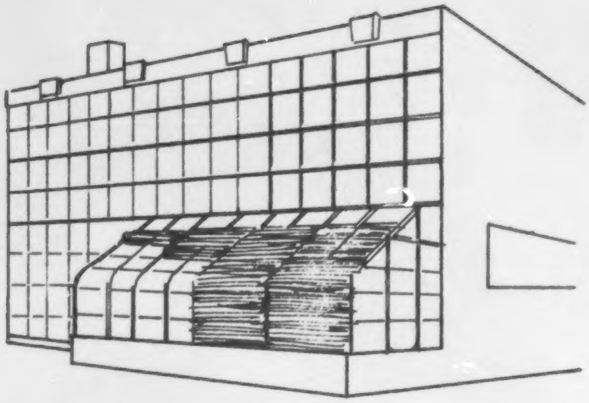
Function:



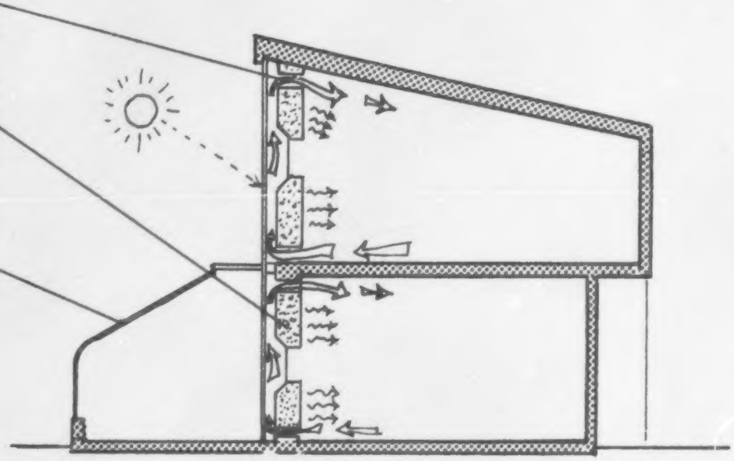
General Design(s):

Design Type:

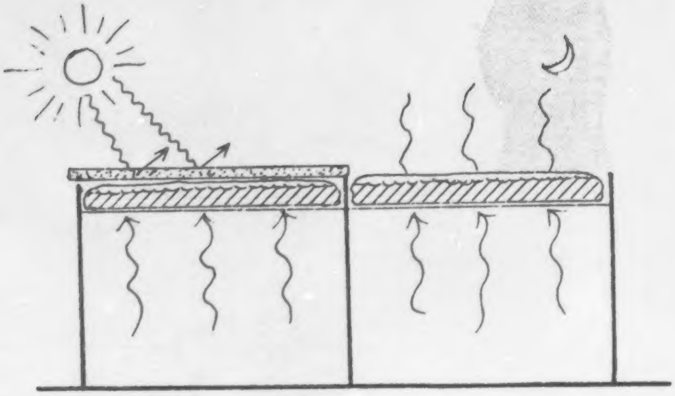
Type of Heat Flow:



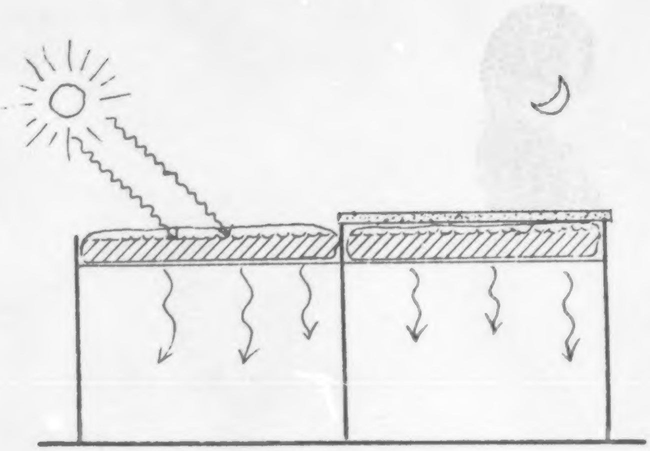
Name These Functions:



Heat Flow Type:



Name
These
Functions:

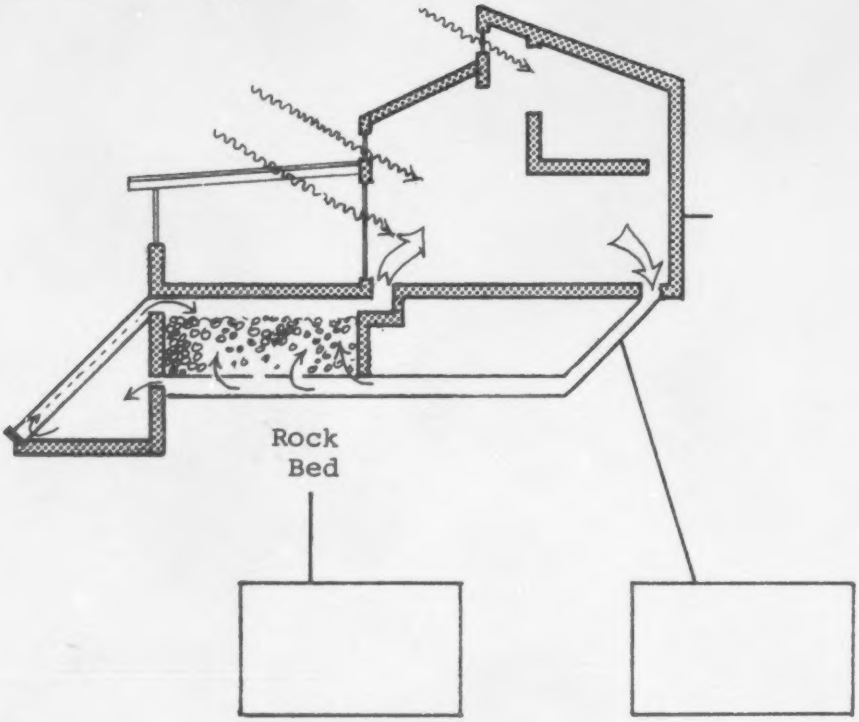


Heat Flow Type:

General Design(s):

Design Type(s):

Type of Heat Flow:



Name These Functions:

2. Find out from suppliers and other knowledgeable persons, the approximate costs of the following heat storage devices for your area. For each, include materials and on-site labor costs. Be very specific.

Name source and contact for information

1. Brick Floor (sq ft)

2. Concrete Floor, 4" thick (sq ft)

3. Gypsum Board (sq. ft.)

4. Concrete Block Wall, holes filled with sand, insulated outside, with protective facing (sq ft)

5. Concrete Wall (140 lb/cf) 10" thick (sq ft)

6. Brick Wall (sq ft)

7. UV stabilized 20 mil plastic water bags (check w/ water bed manufacturer)

8. 18 gauge, ribbed steel deck (sq ft)

9. Gabion: Wire basket filled with rocks, used in dams and spill ways

10. Oil Drums - Rust resistant-supported on framework

DESIGN CONSIDERATIONS

Making use of the sun's energy to heat and cool houses with few or no mechanical or electronic aids is a real challenge. To use this free source of energy, our houses must meet three requirements:

Requirement (1): The house must let sunlight in in cold weather, and keep it out when the weather is too hot. There are four main ways to make this happen:

(a) the shape of the house

(b) the direction it faces

(c) the type of windows it has

(d) the type of shade it receives.

Requirement (2): The house must be able to absorb and hold heat, and release it when it's needed. Construction materials are important, when the house has to heat and cool itself.

Requirement (3): The house must be a good heat barrier. It must be well-insulated and tightly constructed, so it can keep stored heat in where it's needed, or keep overheated air out, in the summer. Most good insulating materials are very poor at heat storage, and most good heat storage materials (brick, concrete, water) are poor insulators.

This information sheet discussed Requirements (1) and (2)--the house as solar collector, and the house as store house for heat. Most insulation and energy conservation methods are discussed in Unit SB-1.

The House as Sun Trap. The best way to use the sun is to face the house so as to get the most insolation in the winter and least in the summer. In the south, houses which are oriented to the southeast get the most winter insolation when the air is coolest (in the morning). The east and west walls get the heaviest insolation in the summer so these should be narrower than the south wall. The best orientation looks about like this, according to several who have studied this question:

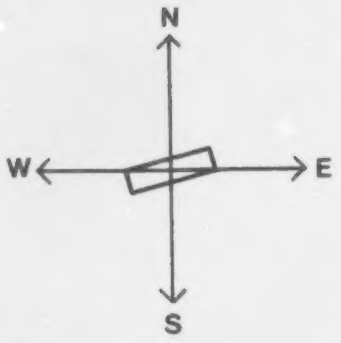


Figure 7.

In the winter, the sun rises south of east, and sets south of west, so the south side should have many windows. In Atlanta a single pane window on the south wall gains 9 Btu/hr/sq ft, when the sun is shining, even allowing for loss of house heat through it.

More About Windows

Windows may be made of clear, heat absorbing, or reflective glass. They may be single, double, or triple glazed. For the south side, single or double glazed clear glass is best. Double glazing of clear glass on the south wall in Atlanta gains 78.8 Btu/hr/ft sq more than it loses. They gain as much heat as single layers of glass, and lose less. Summer heat gain can be reduced to 31 percent of normal by double glazing using reflective glass outside and heat absorbing glass inside. Such glass should never be used on the south side, but may be helpful for east and west windows. The fewer windows on the north side, the better.

The House as Heat Store

Color. The color of a house affects how well it heats or cools its occupants. You have probably observed this fact, with respect to cars. In the summer, on a sunny day, the surface of a black car is likely to be too hot to touch, while the surface of a white car beside it is comfortably cool to the touch.

The ideal surface for a house (from a comfort standpoint) would be one which was black in winter and white in the summer. Such a surface doesn't exist, and a balance must be chosen. The table below shows common exterior surfaces for houses, ranked in order of their ratio of absorptance (ρ) to emittance (ε). Absorptance is the percent of solar radiation absorbed by a surface. Emittance is the relative amount of thermal energy given off by that surface. A large α/ε ratio is desirable for south-facing surfaces, which get much winter sun; a small α/ε ratio is best for areas that get strong sun in the summer, like west walls shading. We don't have house surfaces that change with the season, but we do have an important tool to automatically control solar heat gain with the seasons--deciduous trees. Shading of south and west walls with trees which lose their leaves in the winter is smart design. Trellises with vines which grow only in the summer are also valuable aids for south and west walls. Such devices (see sketch below) can be natural air conditioners.

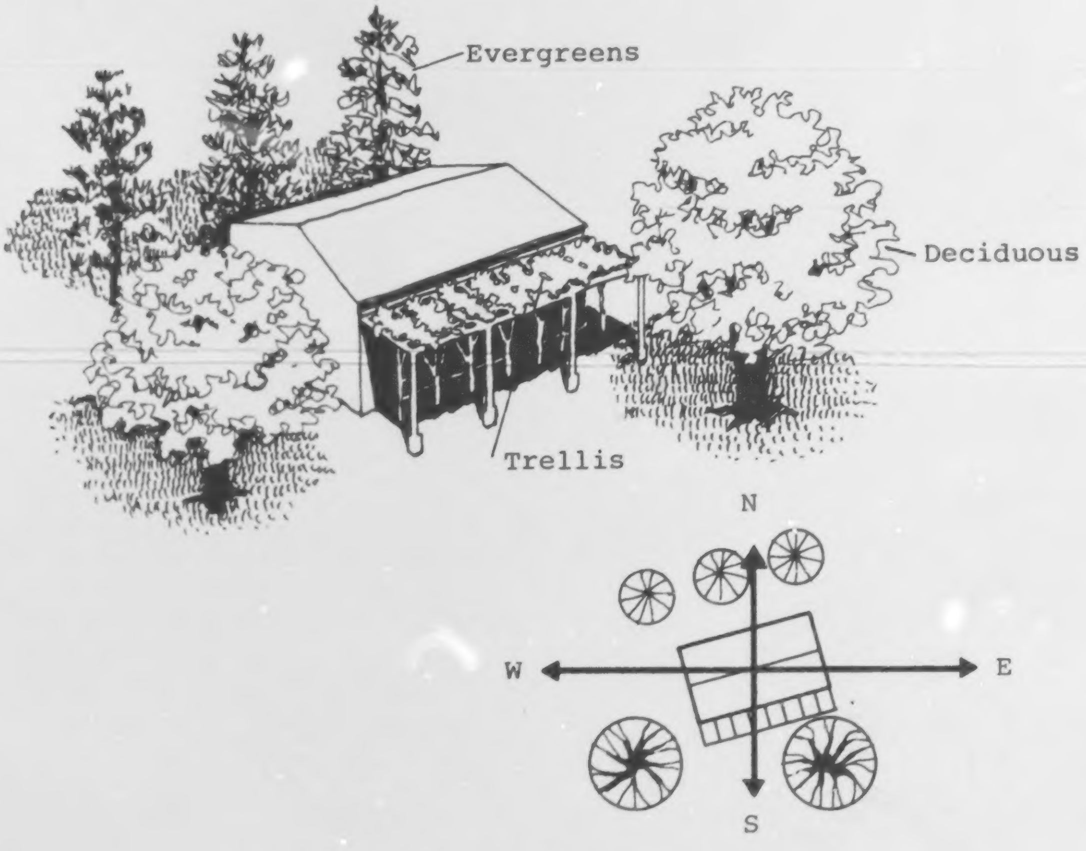


Figure 8.

TABLE SB-2-3-1

ABSORPTANCE (α/ε) FOR COMMON BUILDING MATERIALS

Material	α/ε
White Plaster	0.08
White Paint	0.22
Green Oil Base Paint	0.56
Red Brick	0.60
Concrete	0.68
Grey Paint	0.79
Red Oil Base Paint	0.82
Dry Sand	0.91
Green Roll Roofing	0.94
Black Tar Paper	1.00
Black Glass Paint	1.00
Flat Black Paint	1.09
Granite	1.25

Storing Heat. The simplest way to store heat in a house is in the materials of which the house is built. Unfortunately, recent home building techniques have not used this simple principle. Even a very well insulated home will lose heat quickly if it is built from materials that don't store heat well. In general, heavy materials are good means of heat storage. Heavy materials used in construction can do two things to aid comfort conditioning a house:

(1) When the house is absorbing solar energy, heavy materials soak up the heat from the air, preventing it from becoming overheated.

(2) When the sun goes down, heavy materials give off their stored heat to the air of the house. These materials also will give off their heat to the cold outside air, unless they are insulated from the outside air. Present construction techniques do not recognize this principle. If brick for example, is used, it is used as a facade, with insulation between it and the living areas. Better practice would be to use brick or concrete next to the inside surface, with insulation and a protective surface on the outside.

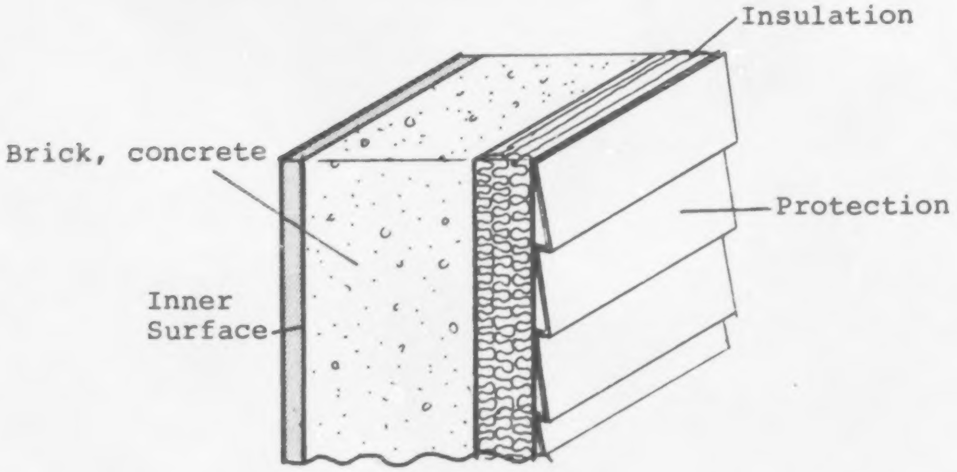


Figure 9.

The table below lists the heat capacities of common building materials.

The heat capacity is the amount of heat (in Btu) required to raise one cubic foot of the material 1° F. Thus, if a cubic foot of concrete heats up to 10° F, it has stored 317 Btu's. And, if a cubic foot of concrete cools 10° F, it gives off 317 Btu's to its surroundings (31.7 x 10° F = 317 Btu). You can see how this can be put to practical use in the following example.

Example: Using Heat Storage Capacity. Suppose a well-insulated house has been built with 200 square feet of brick wall in the interior. The wall is 9" thick, and so provides 150 cubic feet of heat storage capacity. Sunlight from south facing windows has warmed the wall to 75° by the end of one winter day, so the wall has stored heat that can be used. When will it be used?

Later that night the stored heat can be used. For example, if the air temperature in the house is 65°, and the air temperature outside the house is 35°, a difference of 30° exists, which of course causes house heat to move outwards. How fast that happens depends on how well-insulated the house is. If this house is well-insulated, it may lose 400 Btu per hour, for each degree of difference between the inside and outside air. That is,

(1) Heat loss/hr = 400 Btu $(65^\circ - 35^\circ) = 400 \times 30 = 12{,}000$ Btu/hr.

If no heat store exists, then a furnace must provide this much heat to keep the inside air at 65°. In our example house, however, the brick interior walls have stored heat. This wall can give off 24.6 Btu for each cubic foot for each degree difference between its temperature and the air temperature. That is,

(2) Potential Heat Contribution From Wall = $(24.6 \times 155) \times (75^\circ - 65^\circ) = 39{,}230$ Btu

If the wall temperature drops ten degrees then, it can give off 39,230 Btu. Since the house is losing heat at the rate of 12,000 Btu/hr, the wall alone can provide enough heat to keep the house at 65° for more than three hours.

(3) $39{,}230 \div 12{,}000 = 3.8$ hrs without auxiliary heating

---

Important: Thermal mass of about 30 Btu/°F per square foot of south facing window is needed, if the mass is exposed directly to the sun. If the mass is not exposed to the sun, about 120 Btu/°F per square foot of south window is needed.

Containers of water inside a house can also do the same job. A gallon of water weighs 8.4 lbs, and has a specific heat of 1. Thus, 8.4 lbs of water can store 8.4 Btu for each 1° F rise in temperature. Other ways to add thermal mass to houses include: using insulated concrete slabs, massive fireplaces, interior partitions of concrete, or concrete blocks filled with sand, or brick, or several inches of brick on the floor. Even extra layer of gypsum board on interior surfaces may help. Gravel or sand beds may be located in crawl spaces. Fans are used to circulate over-heated air through there.

The heat is stored for later use, when cooler room air is circulated through the warmed rocks and back to the living space.

You have read about the following ways to comfort-condition a house:

TABLE SB-2-2

HEAT CAPACITIES OF COMMON MATERIALS

Material	Heat Capacity (Btu/ft^3/$^\circ$F)
Water	62.5
Concrete	31.7
Asphalt	29.0
White Oak	26.8
Brick	24.6
Gypsum	20.3
Sand	18.1
White Pine	18.1
White Fir	17.6
Air	0.018

Make the House a Solar Energy Trap

- Orient its long walls to the southeast
- Provide much glass on the southeast wall
- Shade the southeast wall with plants that lose their leaves in winter
- Use heat absorbing surfaces on south walls
- Use heat-reflecting surfaces on west walls and roof

Make the House a Heat Store

- Build with massive materials
- Insulate there from the outside
- Add heavy materials inside
- Use water containers in front of sunny windows

These designs principles can aid in making the house itself work to keep its occupants comfortable. The Solar Home Book by Bruce Anderson discusses these principles in much greater detail, as well as much else, and is highly recommended reading.

1. Suppose a house loses 300 Btu/hr/°F. It is built on a concrete slab 20' x 20' x 4" thick. If the concrete slab is warmed to 75° on a winter day, and the house air is 65°, if the difference (on the average) between inside air and outside during the night is 30°, how many hours can the slab heat the house to 65° before auxiliary heat is required?

2. Suppose you are the heating and air conditioning contractor for a group of speculative homes that are to be built. Part of the land involved is a long east-west ridge sloping down on the south side. What recommendations can you make about siting the homes to be built along that ridge?

3. Use of passive design principles in new construction can reduce heating and cooling loads on active systems by 50 percent or more. What three reasons can you think of that will prevent greater use of these principles?

4. What ways can you think of to encourage the greater use of passive design principles in building construction?

1. Why do most picture windows not contribute to house heating?

2. Name three commonly used types of thermal storage materials.

3. Name several controls for direct gain systems.

4. Why are overhangs not good controls for east or west windows?

5. How can convection be used in the Mass Trombe Wall to provide summer cooling? That is, what controls must be available to make this possible?

6. Using the Survey text, select one house from the Indirect Gain type, and one from Direct Gain type, which you believe would be both "saleable" and effective as passive solar systems in your area. Tell why you chose these, from the standpoint of style, climatic data, building materials, size, etc. (Each of the above criteria should be addressed for an adequate answer.)

7. Name desirable controls for a Water Trombe Wall.

1. What climate will permit a roof pond system to be used for summer cooling?

2. Why would a "roof pond" sometimes be located in an attic?

3. Name three example of a "sunspace."

4. Why is thermal mass necessary in a "Sunspace?"

5. Name essential controls for "Sunspace" type passive systems.

6. What is a convective loop?

JOB SHEET SB-2-1

Materials: Cassette Tape Recorder and Tape

Procedure:

(1) Pretend you are a salesman for "Sun-Tempered Homes, Inc." Find a volunteer to pretend to be a prospect who has agreed to talk with you about passive solar for about 20 minutes.

Tell your prospect about the advantages and disadvantages of passive solar approaches in your area. Include in your presentation:

(a) what passive is

(b) how well it can work

(c) what construction modifications are needed

(d) what the major types are

(e) what the costs may be

(f) how it can be an advantage in your area

Ask your prospect for his reactions and questions about what you have said. Answer these as best you can.

Tape record this whole conversation. Listen to it and rate yourself on the following scales, as honestly as you can.

Clarity of Presentation	(Circle one)	Very Confusing 1	2	3	4	5	6	Very Clear 7
Accuracy (check with your course materials)	(Circle one)	Many wrong statements 1	2	3	4	5	6	No wrong statements 7
Overall "Sales" Value of your presentation	(Circle one)	A real "turn-off" 1	2	3	4	5	6	Prospect "sold" 7

97

(2) Repeat this exercise until your score for each of the rating scales is above average. Play the tape for your instructor for grading as part of the Unit Test.

SOLAR HEATING SYSTEMS CURRICULUM
UNIT LISTING

PHASE A: BASIC UNDERSTANDING

Unit	Task
SA-1	Explain the value of solar energy and principles of solar radiation.
SA-2	Describe basic solar system components and their functions.

PHASE B: DESIGN

Unit	Task
SB-1	Recommend non-solar energy conservation measures.
SB-2	Select passive solar approaches for new construction.
SB-3	Recommend collectors.
SB-4	Recommend and site the thermal storage unit.
SB-5	Recommend control devices.
SB-6	Recognize and describe modes of solar system operation.
SB-7	Calculate heat load for space or domestic hot water heating.
SB-8	Size solar system components.
SB-9	Perform a solar system economic analysis.
SB-10	Recommend a domestic hot water system.

PHASE C: INSTALLATION

Unit	Task
SC-1	Recommend correct thermal mass for direct gain system; fabricate and install modular wall units for passive solar.
SC-2	Schedule solar installation.
SC-3	Install a liquid storage tank.
SC-4	Site and mount collectors.
SC-5	Install liquid collectors and outside plumbing.
SC-6	Install inside plumbing for collector load side loops.
SC-7	Install controls and wiring.
SC-8	Start up system.

PHASE D MAINTENANCE

Unit	Task
SD-1	Maintain the solar system.
SD-2	Troubleshoot solar system problems

MAJOR BLOCK Solar Systems (Phase B: Design) **NAME** ____________

TASK Recommend Collectors

UNIT SB-3 **TIME** (est.) ________ (act.) ________

OBJECTIVE(S) The student will be able to:

1) Identify and describe the functions of the components of collectors, and characteristics contributing to their quality.
2) Describe differences between air and liquid systems, their advantages and disadvantages.
3) Describe and use methods to prevent collector freezing and corrosion.

START ➔		W-1	L-1	A-1	W-2	W-3	A-2	L-2	C-1
L-3	W-4	L-4	C-2	W-5	L-5	W-6	L-6	C-3	W-7
L-7	C-4								

WRITTEN ASSIGNMENT(S)		**AUDIOVISUAL(S)**	
W-1	Assignment SB-3-1	A-1	Slide Set SB-3-1
W-2	Assignment SB-3-3	A-2	Slide Set SB-3-2
W-3	Assignment SB-3-4	A-3	
W-4	Assignment SB-3-6	A-4	
W-5	Information Sheet SB-3-1	A-5	
W-6	Information Sheet SB-3-2	A-6	
W-7	Assignment SB-3-9	A-7	

LABORATORY ASSIGNMENT(S)		**CHECKPOINT(S)**	
L-1	Assignment SB-3-2	C-1	Progress Check (peer quiz)
L-2	Assignment SB-3-5	C-2	Observation
L-3	Job Sheet SB-3-1	C-3	Progress Check (teacher oral quiz)
L-4	Job Sheet SB-3-2	C-4	Test
L-5	Assignment SB-3-7	C-5	
L-6	Assignment SB-3-8	C-6	
L-7	Assignment SB-3-10	C-7	
L-8		C-8	
L-9		C-9	

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Superintendent of Schools
1979

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ACTIVITY SEQUENCE SHEET

Activity	Flow Chart	Description of Activity
Assignment SB-3-1	W-1	Read Fundamentals, page 3-1 to 3-5 (up to "Heat transfer systems")
Assignment SB-3-2	L-1	Answer study questions on Assignment Sheet SB-3-2
Slide Set SB-3-1	A-1	View Slide Set SB-3-1.
Assignment SB-3-3	W-2	Read Fundamentals, page 3-5 to 3-8 (from "Heat transfer systems" up to "How efficient is a flat plate solar collector?")
Assignment SB-3-4	W-3	Review Figure 1-12 (page 1-6) in Fundamentals. Note that Figure 1-12(B) should be labeled "warm water system"
Slide Set SB-3-2	A-2	View Slide Set SB-3-2.
Assignment SB-3-5	L-2	Answer study questions on Assignment Sheet SB-3-5.
Checkpoint	C-1	Progress check (peer quiz.)
Job Sheet SB-3-1	L-3	Do activity described on Job Sheet SB-3-1.
Assignment SB-3-6	W-4	Review Fundamentals, Figures 1-5 and 1-6 (page 1-3). Pay careful attention to the differences between air and liquid collectors.
Job Sheet SB-3-2	L-4	Do activity described on Job Sheet SB-3-2.
Observation	C-2	Observation by instructor of activity described on Job Sheet SB-3-2.
Information Sheet SB-3-1	W-5	Read Information Sheet SB-3-1.
Assignment SB-3-7	L-5	Do study questions on Assignment Sheet SB-3-7.

Information Sheet SB-3-2	W-6	Read Information Sheet SB-3-2.
Assignment SB-3-8	L-6	Do study questions on Assignment Sheet SB-3-8.
Progress Check	C-3	Teacher oral quiz.
Assignment SB-3-9	W-7	Read Fundamentals, page 3-8 to 3-9 (from "How efficient is a flat plate solar collector" to end of chapter).
Assignment SB-3-10	L-7	Do study questions on Assignment Sheet SB-3-10.
Test	C-4	Written.

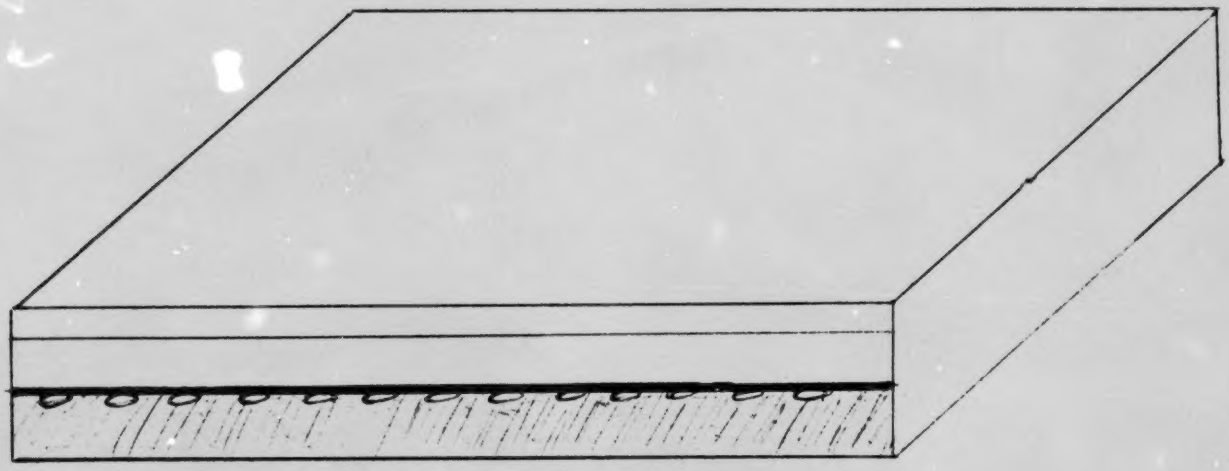
Collector Components

Answer the following questions:

a. What is the greenhouse effect? What causes it?

b. List two ways in which concentrating and flat plate collectors differ in function.

c. In the diagram below, identify each of the major components of a flat plate collector. Is this a one or two cover collector? _________



d. Would the collector above be more effective in warmer or colder climates? Why?

e. How can the efficiency of a transparent cover be increased?

f. Describe factors contributing to the efficiency of the absorber plate. Describe an ideal absorber plate.

Air vs. Liquid Collectors

Answer the following study questions:

a. What is the function of the heat transfer system?

b. In air collectors, why are fins, gauze, glass plates, etc., included in the collectors?

c. In liquid collectors, how does tube configuration affect collector functioning?

d. In liquid collectors, should the design allow the liquid to travel up or down when heated? Why?

e. Describe two possible problems when liquid collectors are used. Briefly mention possible solutions.

f. Describe desirable characteristics for collector insulation material.

g. Describe desirable characteristics for collector frames.

h. In the chart below, indicate the advantages and disadvantages of air vs. liquid systems.

	Advantages	Disadvantages
Air Solar System		
Liquid Solar System		

EXAMINING COLLECTOR PERFORMANCE

Materials

2 real or model liquid solar collectors, one with a black absorber plate and one with a non-black absorber plate. Each collector should be adjustable for having one or two transparent covers.

Thermometers for measuring collector liquid temperature

Data collection sheets

Procedure

A. Morning collector performance: 1 cover plate (To be done between 9 and 10 A.M.)

1) Fill each collector (one with black absorber plate and one with non-black absorber plate) with cool tap water.

2) Measure the temperature of the fluid in each collector for three minutes. If the temperatures for the two collectors are not equal, add warmer or cooler water to equalize the temperatures.

3) Record the equalized, adjusted temperature on the data sheet. It will be referred to as T_i, or initial temperature.

4) Arrange each collector so that it has one transparent cover plate.

5) Place the collectors side-by-side where they are exposed to sunlight. Leave them in the sun for 45 minutes. Make sure each is oriented in the same direction towards the sun, and is at the same tilt angle, if there is a tilt angle.

6) Remove the collectors from the sun, and measure the collector liquid temperature. Record this temperature on the data sheet as T_f, or final temperature.

7) Empty the collectors, and allow the absorber plate to return to room temperature.

B. Noon collector performance: 1 cover plate (To be done at solar noon)

1) Determine the time of solar noon for your area.

2) Repeat Steps 1 through 6, as described in Part A. The collectors should be placed in the sun as close to solar noon as is possible. Record T_i and T_f for each collector, and the times of measurement on the Data Sheet.

C. Morning collector performance: 2 cover plates (To be done between 9 and 10 A.M.)

1) Repeat Steps 1 through 3, as described in Part A.

2) Arrange each collector so that is has two cover plates.

3) Repeat Steps 5 through 7, as described in Part A.

D. Noon collector performance: 2 cover plates (To be done at solar noon)

1) Repeat Steps 1 through 3, as described in Part A.

2) Arrange each collector so that it has two cover plates.

3) Repeat Steps 5 and 6, as described in Part A, placing the collectors in the sun as close to solar noon as is possible.

DATA COLLECTION SHEET

1 Transparent Cover

	Black Absorber Plate	Non-Black Absorber Plate
Morning:		
Time of Measurement =	$T_i=$	$T_i=$
Time of Measurement =	$T_f=$	$T_f=$
Noon:		
Time of Measurement =	$T_i=$	$T_i=$
Time of Measurement =	$T_f=$	$T_f=$

2 Transparent Covers

	Black Absorber Plate	Non-Black Absorber Plate
Morning:		
Time of Measurement =	$T_i=$	$T_i=$
Time of Measurement =	$T_f=$	$T_f=$
Noon:		
Time of Measurement =	$T_i=$	$T_i=$
Time of Measurement =	$T_f=$	$T_f=$

Answer the questions below. Refer to the collected data to support your answers.

a. When was T_f the highest? Why was this so?

b. Which seemed most important to temperature increases: The nature of the absorber surface, the number of cover plates, or the time of day? Explain your response.

c. Why were the collectors tilted and oriented in an identical manner?

d. If the outdoor temperature had been much colder, would there have been a bigger difference in T_f for one versus two cover plates? Why?

e. How could the collectors have been better designed to capture more heat?

Analysis of a Collector

As a solar systems technician, you will probably be called upon to explain the components and operation of a solar collector to a customer. In doing this you will probably want to identify a given collector as an air or liquid collector. To convince your customer of the collector's heat gathering ability, you may want to point out its components, and how they function in the heat gathering process.

To practice this task, ask a fellow student to pretend s/he is a potential solar systems customer. Try to choose a student who hasn't yet studied collectors, and who has real questions about collectors. Obtain a real collector, preferably in cross section, from the instructor, and analyze its qualities for your customer. Encourage him/her to let you know if your explanation is unclear or incomplete.

Ask your instructor to observe this interaction.

COLLECTOR LOOPS: OPEN VERSUS CLOSED

A term frequently used when discussing solar systems is the term "collector loop." The collector loop includes the collectors and all other components through which the collector fluid must travel between the time it leaves the collector, heated, and returns to the collector, cooled. Several types of collector loops are possible. For example, Figure 1 illustrates a liquid system in which an antifreeze solution is circulated through the collectors, and a heat exchanger is used to transfer heat to the storage tank.

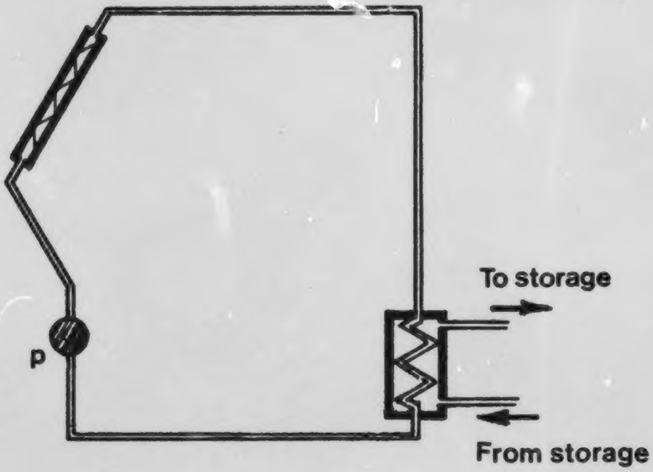


Figure 1

In this system, the collector loop is separate from the storage loop (the storage tank and its connective piping and pumps.) Figure 2 illustrates a liquid system where the same fluid travels through the collectors and into the storage tank. Here the storage tank is included in the collector loop.

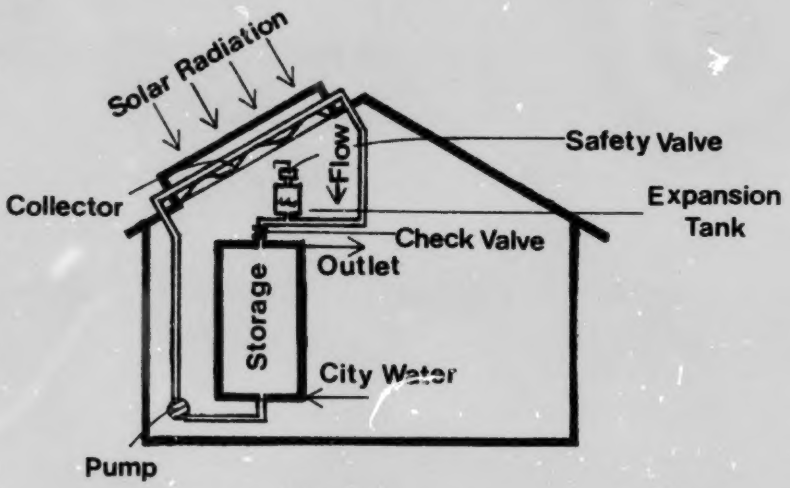

Solar Radiation
Safety Valve
Flow
Collector
Expansion Tank
Check Valve
Outlet
Storage
City Water
Pump

Figure 2

Collector loops are usually described as open or closed loops. An open loop is one in which the liquid is exposed to air somewhere in the loop. This frequently occurs in domestic hot water systems circulating pure water, where freezing is prevented by draining all water out of the collectors into a water tank. In such a "drain-down" system, there is usually an air vent in the water tank, which exposes the water to air. Figure 3 illustrates an open loop system.

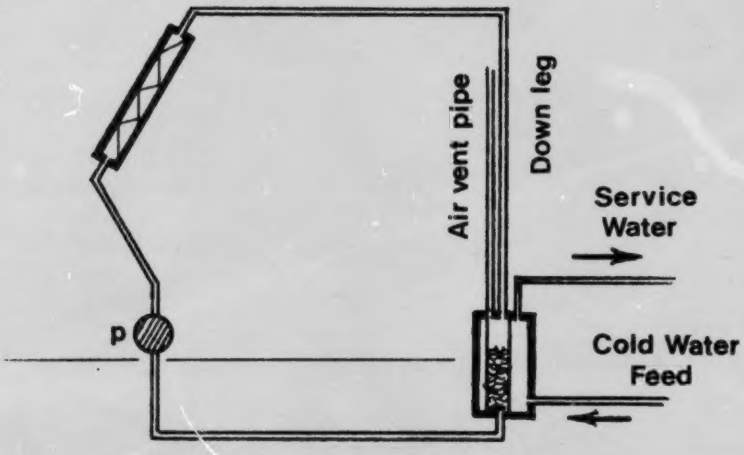

Air vent pipe
Down leg
Service Water
p
Cold Water Feed

Figure 3

Closed collector loop systems are not open to air at any point. They circulate the same liquid over and over again (see Figure 1). In colder climates, the liquid must be protected from freezing, usually by inclusion of an antifreeze additive. This additive increases the expense of the collector fluid. In addition, it must be frequently checked for decomposition that may occur over time.

Closed loop systems generally can include less powerful pumps than can open loop systems. In closed loop systems the weight of the heated liquid traveling away from the collector (usually downwards) helps push the cooled liquid back into the collector (usually upwards). This means there is less work for the pump to do. The pump in the open loop system must be capable of pumping all the water from the water tank back up into the collectors, after a drain-down has occurred. In this case, there is no liquid in the downward part of the loop from the collectors to help push the liquid up into the collectors.

In addition, closed loop systems are less subject to internal corrosion than are open loop systems. The liquid in a closed loop is never exposed to oxygen, which tends to speed corrosion.

ASSIGNMENT SHEET SB-3-7

Collector Loops

Answer the study questions below:

a. What is the "collector loop?"

b. What is the difference between an open and a closed loop?

c. List advantages and disadvantages to open loops and to closed loops, using the table below.

	Advantages	Disadvantages
Open Loop		
Closed Loop		

CORROSION

Table 1 lists a galvanic series of metals and alloys in aqueous solutions. In the list, the metals at the top are easily corroded, while those at the bottom are not easily corroded in an aqueous solution.

TABLE 1

Galvanic Series of Metals and Alloys in Aqueous Solutions

Easily Corroded	Magnesium
	Zinc
	Aluminum
	Steel or Iron
	Cast Iron
	Lead Tin
	Brass
	Copper
	Bronze
	Chromium-Iron
	Silver
Difficult to Corrode	Graphite
	Gold
	Platinum

Magnesium is sometimes used for sacrificial anodes to protect zinc, iron, brass, copper, and bronze but this must not be done if aluminum pipes or absorbers are used in a water system.

Electrolytes, other than hardness and alkalinity, promote corrosion. The presence of calcium, bicarbonate, metaphosphate, and monohydrogen phosphate ions assist in corrosion control. The presence of silica, organic color, and borax is beneficial. Factors which aid corrosion of metals in aqueous solutions are dissolved oxygen, acids, sulfides, tin, copper, cobalt, nickel, and lead, as well as the presence of magnesium (in aluminum systems), chloride, sulfate, nitrate, carbonate, and hydroxide ions. Water circulated through solar collectors should not be permitted to become acidic because corrosion is more rapid in acidic water solutions than in neutral or slightly basic solutions. The water should be drained if it becomes acidic.

Corrosion is minimized when the dissolved oxygen concentration is zero. The free oxygen in an air-tight system collector loop will be lost as some corrosion takes place on the pipes in the system.

A corrosion inhibitor that could be added to the water in the collector loop is presented in Table 2. The recommended concentration in water is 1.5 percent by weight, giving a pH of between 7.5 and 8.0. The inhibitor cost is about 60 cents per pound, and with the suggested mix, the cost is about $70 per 1000 gallons of water.

Automotive grade ethylene glycol solutions also contain corrosion inhibitors. If the composition of the corrosion inhibitor is not given, further information should be sought. One should be especially careful with aluminum tubes and pipes. In general, a 30 percent concentration of automotive grade antifreeze which contains corrosion inhibitors is needed to obtain sufficient protection against rust and corrosion.

Table 2

Composition of a Suggested Corrosion Inhibitor Additive

Concentration	Optimum Percent by Weight
Mercaptobenzothiazole (technical grade, 92% minimum)	15.1
Sodium borate decahydrate $Na_2B_4O_7 \cdot 10\ H_2O$ (borax)	75.7
Anhydrous disodium phosphate $Na_2H\ PO_4$	9.2
	100.0

Removal of small particles by filtration will reduce erosion of the small tubes in the absorber of the collector. A filter which will remove particles greater than 50 microns is satisfactory, but the pressure drop across the filter may be too large if the flow velocity is high. Fifty micron filters may be used initially in the system, and later a change to about 350 micron size may be made.

Heavy metal ions (such as copper and iron) can react with aluminum by displacement of the aluminum and deposition of the other metal. To minimize such ion exchange, an ion getter can be used. An ion getter with an aluminum window screen placed in the pipeline has been used satisfactorily. Various protection devices in a collector loop are shown in Figure 1. A filter, ion getter, and non-metallic hoses connecting pipes of different materials are shown in the figure.

LIQUIDS

Experience indicates that an ethylene glycol concentration of 10 to 20 percent is adequate to prevent pipe and tubing from bursting when exposed to temperatures well below the freezing point of the mixture. If the liquid in the system is static and flow at low temperatures is not required, it is unnecessary to use glycol concentrations as high as inidicated in freezing point tables. However, it is important that the pipes leading to a collector are protected from freezing so that flow is always possible. Otherwise, the liquid in the collector may boil even in mid-winter and, if the pipes are frozen, the tubes in the absorber could burst from excessive pressure.

Adequate freeze protection for a water collector can be obtained with antifreeze concentrations that are less than those required in an automobile radiator, as the purpose of the antifreeze is to prevent damage to the collector, but not to prevent the formation of ice crystals. In Table 3, the temperatures and

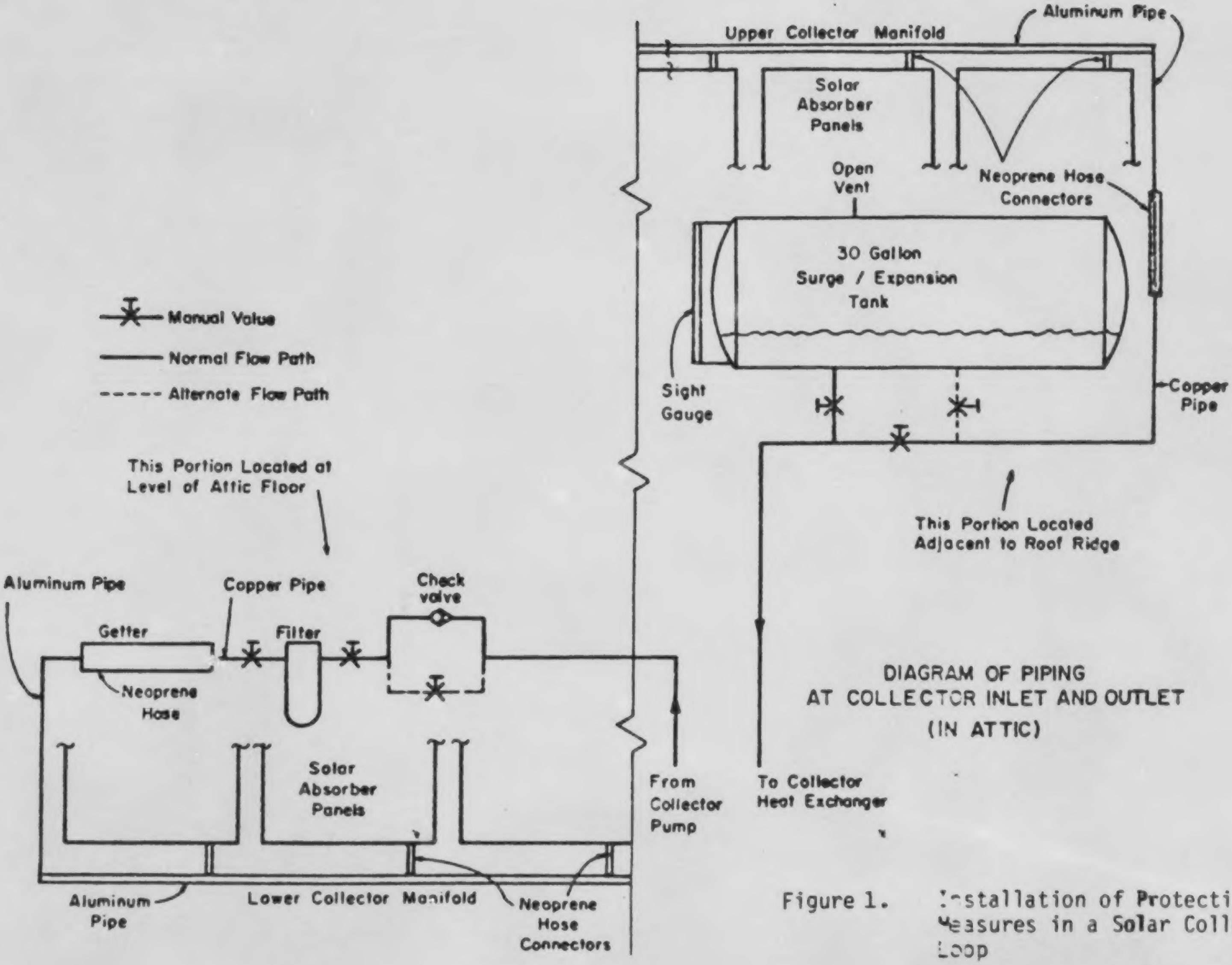

Upper Collector Manifold
Aluminum Pipe
Solar Absorber Panels
Open Vent
Neoprene Hose Connectors
30 Gallon Surge / Expansion Tank
Sight Gauge
Copper Pipe
This Portion Located Adjacent to Roof Ridge
Manual Valve
Normal Flow Path
Alternate Flow Path
This Portion Located at Level of Attic Floor
Aluminum Pipe
Copper Pipe
Check valve
Getter
Filter
Neoprene Hose
Solar Absorber Panels
From Collector Pump
To Collector Heat Exchanger
DIAGRAM OF PIPING
AT COLLECTOR INLET AND OUTLET
(IN ATTIC)
Aluminum Pipe
Lower Collector Manifold
Neoprene Hose Connectors

Figure 1. Installation of Protective Measures in a Solar Collector Loop

percent ethylene glycol concentration in water (by volume) have proven to result in a slushy condition which, while very dense, does not result in damage to the tubes. If the corrosion inhibitor additive in the antifreeze is to be utilized, the minimum concentration should be about 30 percent.

Table 3

Concentration of Ethylene Glycol Required for Freeze Protection

Percent Ethylene Glycol by Volume in Water	Minimum Temperature for Freeze Protection, °F*
0	32
5	26
10	16
15	2
20	-18

*Flow will not be possible below these temperatures.

Thermal decomposition of ethylene glycol takes place at about 329° F. The rate of thermal decomposition is very low in this temperature range and, unless significantly higher temperatures are encountered, thermal decomposition of the antifreeze additive will not be a problem. A maximum temperature of 300° F is suggested in the absence of dissolved oxygen in the solution, and lower temperatures are recommended to extend the service life of the liquid solution.

In the presence of air, ethylene glycol degrades more readily than without air. A portion of the degradation product results in an acidic solution which promotes corrosion. If simultaneous exposure to oxygen and elevated temperatures of the ethylene glycol solution cannot be avoided, then the temperatures must be moderated. The allowable maximum temperature depends upon the degree of aeration and the desired service life of the solution. A temperature of 250° F may be acceptable when the only source of air is a vent or vacuum breaker line. Antioxidants are helpful in some applications. Ethylene glycol concentrations greater than 60 percent by weight are not used because the minimum freezing point is achieved at 60 percent.

The price of two other heat transfer liquids are given in Table 4. Dowtherm J is currently being used in the Phoenix solar heated house in Colorado Springs, Colorado. Therminol 55 is used in high temperature solar collectors. Some of the physical properties of the two liquids are given in Table 5.

Dowtherm J is non-corrosive toward all metals or alloys commonly used in solar systems, such as steel, aluminum, copper, and stainless steel alloys.

Oxidation is a problem when heat transfer fluids at high temperatures are exposed to the atmosphere in open systems. Significant oxidation can cause the fluid viscosity to increase and insoluble material to be formed. The insolubles will decrease the heat transfer rate at the tube walls, increase film temperatures, and accelerate thermal degradation of the tube walls.

Table 4

Cost of Two Heat Transfer Liquids

Quantity and Container Size	Price per Gallon	
	Dowtherm J	Therminol 55
5 gallon cans		16.10
1 drum*	4.60	2.90
5 drums	4.10	2.90
1-9 drums		2.90
20 drums	3.99	2.60
10-59 drums		2.60
60 drums or more		2.20
4,000 gallon tank truck	3.77	
40,000 pounds or more		1.50
*55 gallon drums (each contains 400 pounds of Therminol 55)		

Table 5

Some Physical Properties of Dowtherm J and Therminol 55

Property	Dowtherm J	Therminol 55
Operating temperature range, °F	-100 to 575	-5 to 600
Pour point, °F		-40
Boiling point, °F	358	635
Flash point, °F	145	355
Fire point, °F	155	410
Auto ignition temperature, °F	806	675

Liquid Collectors

Answer the following study questions:

a. Circle the seven (7) metals which are most easily corroded in aqueous solutions: silver, brass, copper, zinc, steel, platinum, bronze, iron, tin, graphite, magnesium, gold, aluminum, chromium-iron, lead, cast iron

b. Why is it inadvisable to circulate acidic water in collectors? What corrective measures should be taken?

c. Why is corrosion less in an air-tight collector loop?

d. What concentration of corrosion inhibitor is recommended? What is the resulting pH level (a measure of acidity)?

e. If automotive grade antifreeze (ethylene glycol) is used to inhibit corrosion, what percent concentration of it in the water is necessary?

f. Describe considerations for using filters.

g. Why is ion getter used?

h. What percent of ethylene glycol should be included in a liquid system to avoid freezing?

i. Why must pipes leading to the collector be insulated?

j. If ethylene glycol is used as both a corrosion inhibitor and an antifreeze, what should be its minimum concentration in the water?

k. What factors cause decomposition of ethylene glycol? What can be done to minimize such decomposition?

l. What problems may be caused by exposure of the collector liquid to air?

Collector Efficiency

Answer the study questions below:

a. What is the efficiency of a collector having an input of 8000 Btu/h and an output of 7000 Btu/h?

b. List two operating conditions under which collector efficiency is decreased.

1)

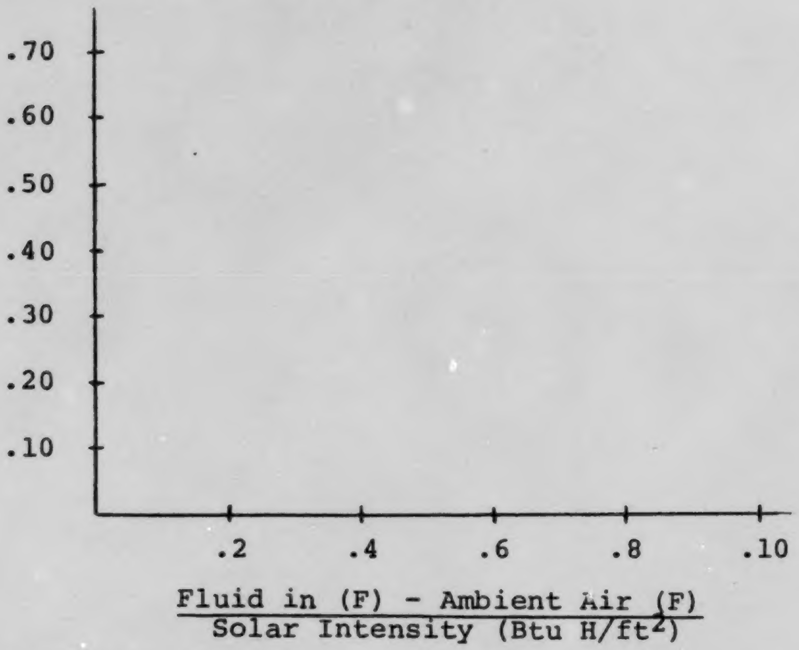
2)

c. Why is the average collector efficiency usually less than the efficiency published in the manufacturers specifications?

d. In the diagram below, plot the efficiency curve for a collector having the following characteristics:

Intercept = .55

Slope = .60 (or 6/10)



e. What is the efficiency of the collector described above under the following conditions:

Fluid temperature = 110° F

Ambient air temperature = 40° F

Solar intensity = 300 Btu H/ft^2

Efficiency =

f. If fluid inlet temperature of the above collector is 130° F, what is the collector efficiency?

g. List the appropriate fluid flow rate for air and liquid collectors.

	Fluid Flow Rate
Liquid collector	
Air collector	

SOLAR HEATING SYSTEMS CURRICULUM
UNIT LISTING

PHASE A: BASIC UNDERSTANDING

Unit	Task
SA-1	Explain the value of solar energy and principles of solar radiation.
SA-2	Describe basic solar system components and their functions.

PHASE B: DESIGN

Unit	Task
SB-1	Recommend non-solar energy conservation measures.
SB-2	Select passive solar approaches for new construction.
SB-3	Recommend collectors.
SB-4	Recommend and site the thermal storage unit.
SB-5	Recommend control devices.
SB-6	Recognize and describe modes of solar system operation.
SB-7	Calculate heat load for space or domestic hot water heating.
SB-8	Size solar system components.
SB-9	Perform a solar system economic analysis.
SB-10	Recommend a domestic hot water system.

PHASE C: INSTALLATION

Unit	Task
SC-1	Recommend correct thermal mass for direct gain system; fabricate and install modular wall units for passive solar.
SC-2	Schedule solar installation.
SC-3	Install a liquid storage tank.
SC-4	Site and mount collectors.
SC-5	Install liquid collectors and outside plumbing.
SC-6	Install inside plumbing for collector load side loops.
SC-7	Install controls and wiring.
SC-8	Start up system.

PHASE D MAINTENANCE

Unit	Task
SD-1	Maintain the solar system.
SD-2	Troubleshoot solar system problems

MAJOR BLOCK Solar Systems (Phase B:Design) NAME ____

TASK Recommend and Site the Thermal Storage Unit

UNIT SB-4 TIME (est.) ____ (act.) ____

OBJECTIVE(S) Student will be able to:
1) Select a storage unit for a particular solar system.
2) Identify advantages and disadvantages of rock, water, phase change storage.
3) Locate and size thermal storage unit, and recognize and be able to correct problems due to incorrect sizing.
4) Recognize and name potential maintenance features of thermal storage units.
5) Describe storage unit operation.

START ➜ W-1 L-1 W-2 L-2 C-1 L-3 C-2 W-3
L-4 W-4 W-5 L-5 C-3 W-6 L-6 W-7 L-7 C-4
L-8 C-5 W-8 L-9 C-6

WRITTEN ASSIGNMENT(S)		AUDIOVISUAL(S)	
W-1	Assignment SB-4-1	A-1	
W-2	Information Sheet SB-4-1	A-2	
W-3	Assignment SB-4-4	A-3	
W-4	Assignment SB-4-6	A-4	
W-5	Information Sheet SB-4-2	A-5	
W-6	Assignment SB-4-8	A-6	
W-7	Assignment SB-4-10	A-7	
W-8	Information Sheet SB-4-3		

LABORATORY ASSIGNMENT(S)		CHECKPOINT(S)	
L-1	Assignment SB-4-2	C-1	Progress Check (written quiz)
L-2	Assignment SB-4-3	C-2	Observation
L-3	Job Sheet SB-4-1	C-3	Observation
L-4	Assignment SB-4-5	C-4	Progress Check (peer quiz)
L-5	Assignment SB-4-7	C-5	Observation
L-6	Assignment SB-4-9	C-6	Test (written)
L-7	Assignment SB-4-11	C-7	
L-8	Job Sheet SB-4-2	C-8	
L-9	Assignment SB-4-12	C-9	

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1979

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ACTIVITY SEQUENCE SHEET

Activity	Flow Chart Number	Description of Activity
Assignment SB-4-1	W-1	Read *Fundamentals*, page 4-1 to 4-2 (up to "Concepts of Heat storage sizing")
Assignment SB-4-2	L-1	Answer questions on Assignment Sheet SB-4-2.
Information Sheet SB-4-1	W-2	Read Information Sheet SB-4-1.
Assignment SB-4-3	L-2	Answer questions on Assignment Sheet SB-4-3.
Progress Check	C-1	Written quiz.
Job Sheet SB-4-1	L-3	Do activity described on Job Sheet SB-4-1.
Observation	C-2	Observation.
Assignment SB-4-4	W-3	Read *Fundamentals*, page 4-2 to 4-4 (from "Concepts of heat storage sizing" up to second column of page 4-4)
Assignment SB-4-5	L-4	Answer questions on Assignment Sheet SB-4-5.
Assignment SB-4-6	W-4	Read *Fundamentals*, page 4-4 to 4-7 (from 2nd column of page 4-4 to "Placement of Heat Storage Units") after reading the comment below.

Comment

The text material describes how building heat loss influences the size of the storage unit. Heat loss calculations are complex and will be covered more thoroughly in another unit of the course. Read carefully through the whole assignment, but focus your attention on the calculations in the top, left column of p. 4-7. These describe how building heat loss is related to storage size.

Activity	Flow Chart Number	Description of Activity
Information Sheet SB-4-2	W-5	Read Information Sheet SB-4-2.
Assignment SB-4-7	L-5	Answer study questions on Assignment Sheet SB-4-7.
Observation	C-3	Observation.
Assignment SB-4-8	W-6	Read Fundamentals, page 4-7 ("Placement of heat storage units," only)
Assignment SB-4-9	L-6	Answer study questions on Assignment Sheet SB-4-9.
Assignment SB-4-10	W-7	Read Fundamentals, page 4-7 to 4-10 (from "Advantages and disadvantages for storing heating liquids" to end of chapter)
Assignment SB-4-11	L-7	Answer questions on Assignment Sheet SB-4-11.
Progress Check	C-4	Peer quiz.
Job Sheet SB-4-2	L-8	Do activity described on Job Sheet SB-4-2.
Observation	C-5	Observation.
Information Sheet SB-4-3	W-8	Read Information Sheet SB-4-3.
Assignment SB-4-12	L-9	Answer questions on Assignment Sheet SB-4-12.
Test	C-6	Written

Introduction to Heat Storage

Answer the study questions below:

a. What is the meaning of the term, "specific heat?"

b. What is the specific heat of water? of rock? What consequence does this difference have for the size of water storage versus rock storage units?

c. How does heat storage occur in a phase change storage system?

d. With current technology, phase change storage is not frequently used. Why is it not often used?

e. What considerations should determine the choice of a storage medium?

Calculating Heat Absorption by a Storage Unit

The number of Btu's absorbed during a temperature change by the material in any storage unit can be easily calculated. The general formula is:

Number of Btu's Absorbed = Total Weight of Storage Material X Specific Heat of Storage Material X Temperature Change

For a water storage unit, the above formula may be rewritten as follows:

Number of Btu's Absorbed =

Volume of Storage Unit (in ga.)	X	8.34 lb/ga	X	1Btu/lb	X	(final temperature - initial temperature in F°.)
↑		↑		↑		↑
Volume of Water		Weight of Water		Specific Heat of Water		Temperature Change

For a rock storage unit, the general formula may be rewritten as follows:

Number of Btu's Absorbed =

Volume of Storage Unit (in ft^3)	X	100 lb/ft^3	X	.20 Btu/lb	X	(final temperature - initial temperature in F°.)
↑		↑		↑		↑
Volume of Rock		Weight of Rock		Specific Heat of Rock		Temperature Change

Examples

Problem 1: A 1500 ga. water storage tank increases in temperature from 120° F to 140° F. How many Btu's were absorbed?

Number of Btu's absorbed =

$$\text{Volume of Storage Unit (in ga.)} \times 8.34\ \text{lb/ga} \times 1\text{Btu/lb} \times (\text{final temperature} - \text{initial temperature in F}^{\circ}.)$$

$$1500 \times 8.34 \times 1 \times (140 - 120) = 250{,}200\text{Btu}$$

Problem 2: A 200 cubic foot rock storage tank increases in temperature from 120° F to 140° F. How many Btu's were absorbed?

Number of Btu's absorbed =

$$\text{Volume of Storage Unit (in ft}^3) \times 100\ \text{lb/ft}^3 \times .20\ \text{Btu/lb} \times (\text{final temperature} - \text{initial temperature in F}^{\circ}.)$$

$$200 \times 100 \times .20 \times (140 - 120) = 80{,}000\text{Btu}$$

Problem 3: How large would a rock storage unit need to be to absorb 250,200 Btu in a temperature change from 120° F to 140° F?

Number of Btu's absorbed =

$$\text{Volume of Storage Unit (in ft}^3) \times 100\ \text{lb/ft}^3 \times .20\ \text{Btu/lb} \times (\text{final temperature} - \text{initial temperature in F}^{\circ}.)$$

Rearranging this formula, we find:

Volume of storage unit(ft^3) =

$$\frac{\text{Number of Btu Absorbed}}{100\ \text{lb/ft}^3 \times .20\ \text{Btu/lb} \times (\text{final temperature} - \text{initial temperature})}$$

$$= \frac{250{,}200}{100 \times .20 \times 20} = 625.5\ \text{ft}^3$$

Storage Size and Heat Absorption

Answer the study questions below:

a. Calculate the number of Btu's absorbed by a 1000 ga. water storage tank which increases in temperature from 140° to 160° F.

b. Note that 1000 gallons is approximately 135 ft^3. Calculate the number of Btu's absorbed by a 135 ft^3 rock storage unit which increases in temperature from 140° F to 160° F.

c. Which type of storage unit absorbed more heat?

d. How large would the rock storage unit need to be to absorb the amount of heat absorbed by the water storage unit?

Building and Observing Simple Storage Units

Materials

2 well-insulated ice chests without tops
2 clear covers for the chests
5 thermometers
2 5-gallon cans painted black with rubber gasket in screw lid top
Caulking
Wire
Graph paper
Props for supporting the chest at latitude level
Pebbles about 3/4 to 1 1/2" in diameter to fill one can
Water to fill one can

Procedure

1. Use the props to tilt the chests at an angle equal to the local latitude, and facing south.

2. In the top of each can lid, make a hole large enough to insert a thermometer. Insert the thermometers in the lid tops so that when the tops are screwed on, the mercury tip will be inside the can, but the can's internal temperature can be read from the outside.

3. Fill one can with cool water, the other can with cool pebbles. Screw on lids, with thermometer inserted, on the top of each can. Use caulking compound to leak proof each can.

4. Place one can in each of the ice chests. Try to orient the cans so the thermometers can be read, but are shaded by the cans or by the ice chest walls.

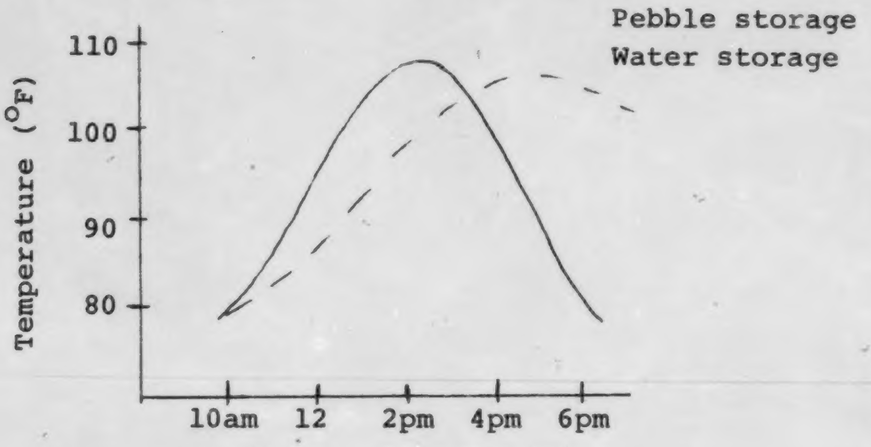
5. Use the wire to install a second thermometer in each ice chest. This thermometer will measure the air temperature in the ice chest, and must be placed in the same place in each chest.

6. Place the clear covers on the chests.

7. Measure and record the initial interior air and storage temperature for each chest. The two chests should initially have equal air temperature and equal storage temperatures. Record these temperatures on the Data Sheet.

8. Measure and record the ice chest air and storage temperatures for each can at the following times for two consecutive days. Also, record the outside air temperature. Record these temperatures on the Data Sheet.

9. Graph the changes in temperature over time to compare the storage and interior air temperatures for the two chests. Your graphs should be drawn on the following Temperature Comparison Sheet. An illustrative graph is shown below.



Storage Temperature

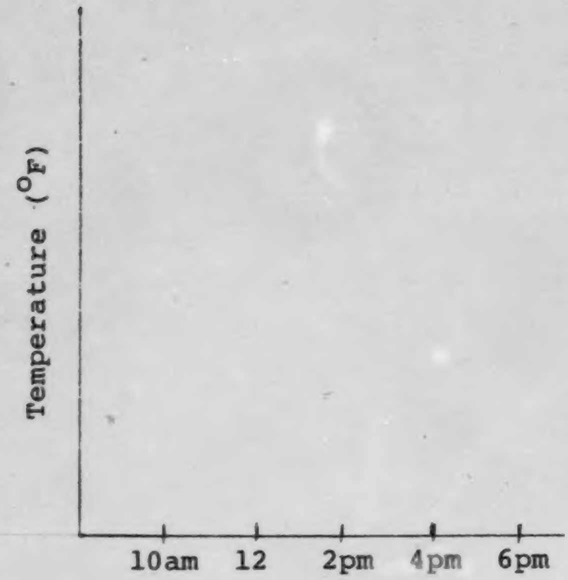
10. Answer the questions on the Question Sheet.

TEMPERATURE DATA SHEET

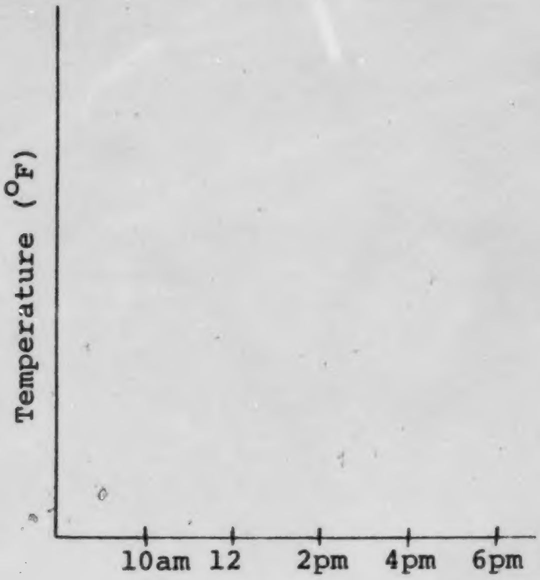
		Chest Interior Air	Storage	Outside Air
Water storage chest				
Initial				
Day 1	10 AM			
	12 Noon			
	2 PM			
	4 PM			
	6 PM			
Day 2	10 AM			
	12 Noon			
	2 PM			
	4 PM			
	6 PM			
Pebble storage chest				
Initial				
Day 1	10 AM			
	12 Noon			
	2 PM			
	4 PM			
	6 PM			
Day 2	10 AM			
	12 Noon			
	2 PM			
	4 PM			
	6 PM			

TEMPERATURE COMPARISON SHEET

Day 1

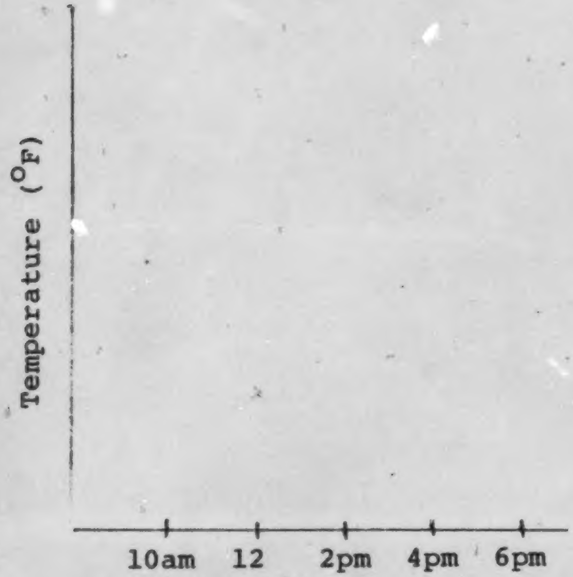


Storage Temperature

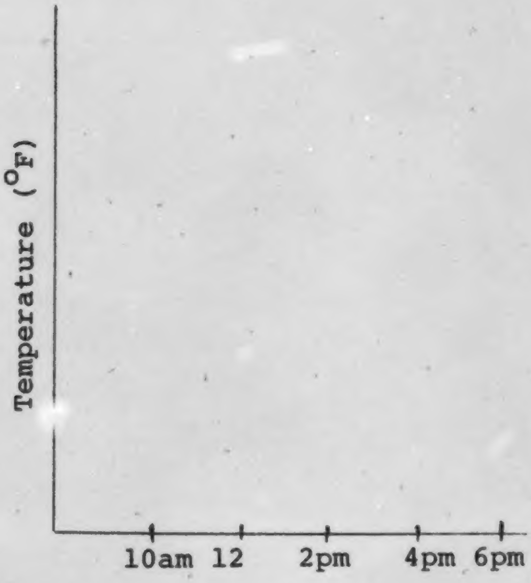


Interior Air Temperature

Day 2



Storage Temperature



Interior Air Temperature

Question Sheet

1. The ice chest cover functioned as the ______________ in a real solar system.
2. The black container functioned as the ______________ in a real solar system.
3. The rocks/water function as the ______________ in a real solar system.
4. The ice chest functioned as the ______________ in a real solar system.
5. Why were the ice chests tilted and faced south?
6. Why were the cans painted black?
7. At what time of the day were the storage temperatures the highest for each storage unit? Why?
8. Was there a difference between the air temperature inside the ice chest and outside the ice chest? Why did this occur?

9. Toward the evening, in which ice chest did air temperature drop more slowly? Why did this occur?

10. Which storage unit reached its highest temperature first? Why?

Sizing Storage Units

Answer the study questions below:

a. What two factors should determine the volume of space for storage?

b. What happens if the storage size is too large, relative to collector heat absorption?

c. What happens if storage size is too small, relative to collector heat absorption?

d. Cite the general rule for estimating a) water storage size from collector size, b) rock storage size from collector size.

e. In a particular solar system, the collector area is 192 square feet.

   1. Estimate the size of necessary water storage in cubic feet. (1 gallon has a volume of about .135 ft^3)

   2. Estimate the size of rock storage.

INFORMATION SHEET SB-4-2

Calculating Storage Size

The formulae for calculating storage size for overnight solar heating based on building heat loss are:

For water storage:

$$\text{Number of Gallons} = \frac{\text{Overnight Heat Load (in Btu)}}{8.34\ \text{lb/ga X 1 Btu/lb X Storage Temperature Change}}$$

For rock storage:

$$\text{Number of ft}^3 = \frac{\text{Overnight Heat Load (in Btu)}}{100\ \text{lb/ft}^3\ \text{X 0.2 Btu/lb X Storage Temperature Change}}$$

Examples

Problem 1: If the overnight heat loss is 157,000 Btu, and the storage temperature rises by 30° F, what size of storage is necessary for water storage?

$$\text{Number of Gallons} = \frac{\text{Overnight Heat Load (in Btu)}}{8.34\ \text{lb/ga X 1 Btu/lb X Storage Temperature Change}}$$

$$= \frac{157{,}000}{8.34 \text{ X } 1 \text{ X } 30} = 627.5 \text{ ga}$$

Problem 2: Under the conditions of Problem 1, what size of pebble storage is required?

$$\text{Number of ft}^3 = \frac{\text{Overnight Heat Load (in Btu)}}{100\ \text{lb/cu}^3\ \text{X 0.2 Btu/lb X Storage Temperature Change}}$$

$$= \frac{157{,}000}{100 \text{ X } 0.2 \text{ X } 30} = 261.67 \text{ ft}^3$$

Sizing Storage Units

If overnight building heat loss is 227,000 Btu, and storage temperature rises 40° F, what size of storage is necessary for:

a. Water storage (in ft^3)? (1 gallon has a volume of .135 ft^3)

b. Rock storage?

Locating Storage Units

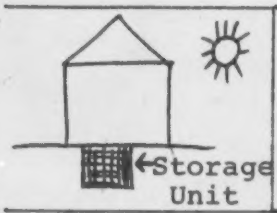
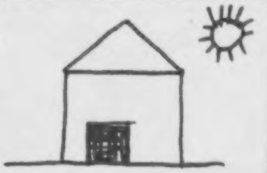
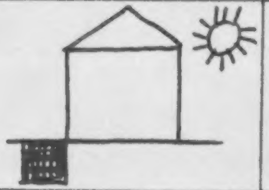
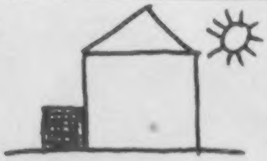
Answer the study questions below:

a. What is the overall, basic rationale that should be applied in choosing a location for a storage unit?

b. Four different types of storage locations are described:

1. Inside the building, below grade
2. Inside the building, above grade
3. Outside the building, below grade
4. Outside the building, above grade

In the chart below, indicate the advantages and/or disadvantages of each location.

	Advantages	Disadvantages
		
		
		
		

CHARACTERISTICS OF WATER & PEBBLE STORAGE UNITS

Answer the study questions below:

a. Describe three advantages of water storage.

b. Describe five disadvantages of water storage.

c. Describe the methods commonly used to minimize problems associated with each of the disadvantages listed above.

d. Describe the kinds of problems which may occur with each of the following kinds of storage tanks:

1. Concrete tank

2. Fiberglass tank

3. Glass-lined tank

4. Galvanized tank

e. Describe ways to construct pebble beds containers.

f. Why should the pebbles be hand shoveled or carefully chuted into the supporting container?

g. Why are cubic pebble beds preferred over horizontal pebble beds?

h. In the space below, illustrate an ideal pebble bed and its operation. You should label your drawing to indicate the following:

pebble size
pebble bed depth
the flow of air during heat storage
the flow of air during heat distribution
the thermal stratification of the storage bed

Analyzing Storage Units

Imagine that you are a solar systems technician working for a heating contractor. Your supervisor asks you to meet with a client to discuss the storage unit that will be installed in the solar system in his house. Pretend that the storage unit in your lab is the one to be installed. Ask a fellow student to pretend s/he is the client. Describe the storage unit to the client, with the goal of helping him/her to better understand the product s/he is buying. Your description might indicate the following:

a. the major components of the storage unit, and their functions

b. special qualities or characteristics of each component, or the storage unit as a whole

c. advantages to this type of storage unit

d. possible problem areas, and corrective measures that can be applied.

As your instructor to observe your performance, and to offer his/her suggestions.

PRINCIPLES OF WATER TANK OPERATION

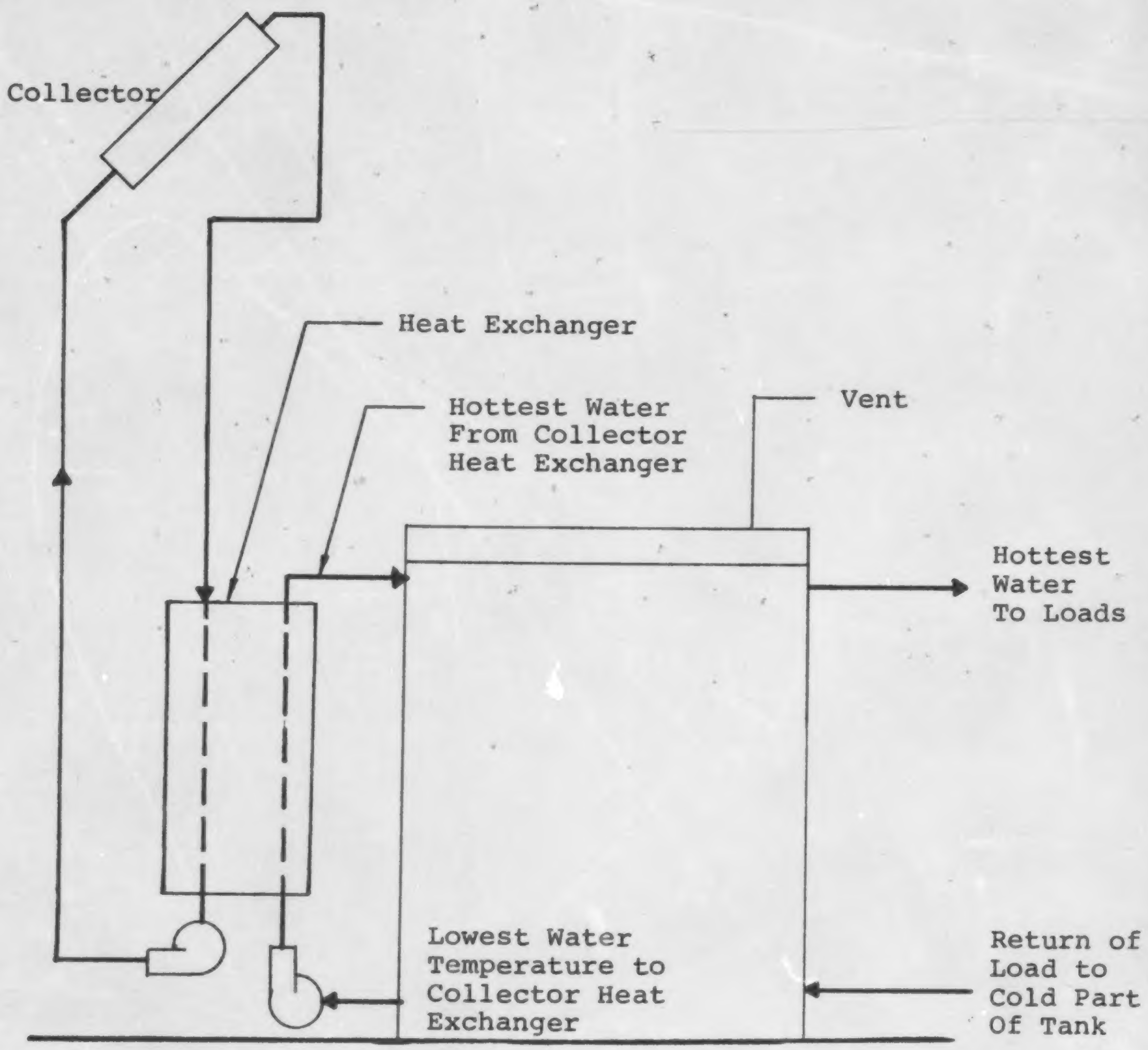
Useful heat is stored between a minimum threshold temperature and a maximum critical temperature, which is usually the boiling point. The minimum temperature is the lowest useful temperature that can provide heat to the load. For space cooling this is about 180° F; for space heating, 90° F; and for service water heating, 60° F. The maximum critical temperature is the boiling point for a vented tank and could be a higher temperature for a pressurized tank. The pressures that will build up in the tank at various temperatures above boiling are listed in Table 1. If the maximum allowable pressure in the tank is 30 psi, for example, the maximum allowable storage tank temperature is 274° F.

Table 1

Maximum Critical Temperature and Maximum Allowable Tank Pressure

Storage Tank Pressure (psi)	Maximum Temperature (°F)
0	212
10	239
20	259
30	274
40	287
50	298

The top of the storage tank will generally be hotter than the bottom, and the magnitude of the temperature difference is a function of tank height and diameter. Any temperature stratification achieved is useful because the lowest temperature possible is pumped to the collector, which improves the performance of the collectors, and the highest temperature available is delivered to the heating coils to heat the house. This arrangement is illustrated in Figure 1.


Collector
Heat Exchanger
Hottest Water From Collector Heat Exchanger
Vent
Hottest Water To Loads
Lowest Water Temperature to Collector Heat Exchanger
Return of Load to Cold Part Of Tank

PEBBLE-BED STORAGE

Solar heated air is passed directly through the pebble-bed from top to bottom. As the air passes through the pebbles, heat is transferred from the air to the rocks so that the rock temperature rises. The cool air which leaves the bottom of the pebble-bed is returned to the collectors to be reheated. The top of the pebble-bed will be warmer than the bottom because of hot air supply from the collectors. After sundown and discontinuance of air circulation, the pebble-bed will maintain this temperature stratification because heat conduction through the bed from one pebble to another is small.

The stored heat is delivered to the building by circulating room air through the pebble-bed in the direction opposite that of the storing cycle, that is, from the bottom toward the top of the pebble-bed. As the cool air flows through the spaces between the pebbles, it is heated and the warm air is recirculated to the rooms. The bottom of the pebble-bed is always at the lowest temperature, usually room temperature, and because the coldest air is delivered to the collectors, the collectors operate at maximum efficiency.

The hot end, or collector supply end, of the pebble-bed is preferably at the top to prevent heat loss to the floor. If the layout requires the hot end at the bottom, two inches of rigid fiberglass board should be placed under the unit to reduce heat loss to the floor.

Comparing Real & Model Storage Units

1) In the activity of Job Sheet SB-4-1, you built and observed the operation of simple water and pebble storage units. Compare these simple units to real water and pebble storage units, in terms of components and operation. How are the simple units different from real units? How are they similiar?

You may use the table below to present your ideas.

	Model Storage Unit	Real Storage Unit
Components		
Means for gathering heat for storage		
Means of distributing heat to air space		

2a) In a real liquid storage unit, the following minimal storage temperatures are necessary

for space heating: __________

for water heating: __________

for space cooling: __________

b) How are the maximum allowable liquid storage tank pressure and the maximal critical temperature related?

SOLAR HEATING SYSTEMS CURRICULUM
UNIT LISTING

PHASE A: BASIC UNDERSTANDING

Unit	Task
SA-1	Explain the value of solar energy and principles of solar radiation.
SA-2	Describe basic solar system components and their functions.

PHASE B: DESIGN

Unit	Task
SB-1	Recommend non-solar energy conservation measures.
SB-2	Select passive solar approaches for new construction.
SB-3	Recommend collectors.
SB-4	Recommend and site the thermal storage unit.
SB-5	Recommend control devices.
SB-6	Recognize and describe modes of solar system operation.
SB-7	Calculate heat load for space or domestic hot water heating.
SB-8	Size solar system components.
SB-9	Perform a solar system economic analysis.
SB-10	Recommend a domestic hot water system.

PHASE C: INSTALLATION

Unit	Task
SC-1	Recommend correct thermal mass for direct gain system; fabricate and install modular wall units for passive solar.
SC-2	Schedule solar installation.
SC-3	Install a liquid storage tank.
SC-4	Site and mount collectors.
SC-5	Install liquid collectors and outside plumbing.
SC-6	Install inside plumbing for collector load side loops.
SC-7	Install controls and wiring.
SC-8	Start up system.

PHASE D MAINTENANCE

Unit	Task
SD-1	Maintain the solar system.
SD-2	Troubleshoot solar system problems

MAJOR BLOCK Solar Systems (Phase B: Design) **NAME**

TASK Recommend Control Devices

UNIT SB-5 **TIME** (est.) ______ (act.) ______

OBJECTIVE(S) The student will be able to:

1) choose appropriate pumps for a given solar system
2) explain the purpose & operation of a heat exchanger
3) describe factors affecting blower operation, and choose blowers
4) name and describe function & operation of control devices in a solar system
5) name & describe function & operation of hydronic specialty devices in a solar system.

START ➔ W-1 ▷ L-1 ▷ W-2 ▷ L-2 ▷ C-1 ▷ W-3 ▷ L-3 ▷ W-4 ▷
L-4 ▷ W-5 ▷ C-2 ▷ C-3 ▷ W-6 ▷ L-5 ▷ C-4 ▷ C-5 ▷ C-6 ▷

WRITTEN ASSIGNMENT(S)		AUDIOVISUAL(S)	
W-1	Assignment SB-5-1	A-1	
W-2	Assignment SB-5-3	A-2	
W-3	Information Sheet SB-5-1	A-3	
W-4	Assignment SB-5-6	A-4	
W-5	Assignment SB-5-8	A-5	
W-6	Assignment SB-5-9	A-6	
W-7		A-7	

LABORATORY ASSIGNMENT(S)		CHECKPOINT(S)	
L-1	Assignment SB-5-2	C-1	Progress check (peer quiz)
L-2	Assignment SB-5-4	C-2	Demonstration (instructor
L-3	Assignment SB-5-5	C-3	Progress check oral quiz)
L-4	Assignment SB-5-7	C-4	Demonstration (instructor
L-5	Assignment SB-5-10	C-5	Progress check oral quiz)
L-6		C-6	Test (written)
L-7		C-7	
L-8		C-8	
L-9		C-9	

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No person shall, on the basis of sex, race, national origin or handicap, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity under the direction of the local education agency.

164

ACTIVITY SEQUENCE SHEET

Activity	Flow Chart Number	Description of Activity
Assignment SB-5-1	W-1	Read Fundamentals, page 5-1 to 5-2 (up to "Air system blowers").
Assignment SB-5-2	L-1	Answer questions on Assignment Sheet SB-5-2.
Assignment SB-5-3	W-2	Read Fundamentals, page 5-2 to 5-4 (sections on "Air system blowers" and "air system heat exchangers").
Assignment SB-5-4	L-2	Answer questions on Assignment Sheet SB-5-4
Progress Check	C-1	Peer quiz.
Information Sheet SB-5-1	W-3	Read Information Sheet SB-5-1
Assignment SB-5-5	L-3	Answer questions on Assignment Sheet SB-5-5.
Assignment SB-5-6	W-4	Read Fundamentals, page 5-5 to 5-9. Pay particular attention to the picture & drawings of the different control devices.
Assignment SB-5-7	L-4	Answer questions on Assignment Sheet SB-5-7
Assignment SB-5-8	W-5	Read Lennox Solar Manual, Controls, p. 1-5.
Demonstration	C-2	Demonstration
Progress check	C-3	Instructor oral quiz.
Assignment SB-5-9	W-6	Read Fundamentals, page 5-10 to 5-14. Pay particular attention to drawings and pictures.
Assignment SB-5-10	L-5	Answer questions on Assignment Sheet SB-5-10.

Demonstration	C-4	Demonstration.
Progress Check	C-5	Instructor oral quiz.
Test	C-6	Test written

a. Specifications for pumps usually describe the following characteristics of the pump: the ______________ and ______________.

b. A type of pump usually used in solar systems is called a ______________ pump.

c. Head pressure refers to:

d. Do open or closed loops require more powerful pumps? Why?

e. In measuring pressure, one foot of water = _______ pounds per square inch (psi).

f. Pump capacity (increases, decreases) as resistance increases.

g. Pumps in collector loops should be able to stand pressures of ________ psi, and temperatures of ________.

h. Open loop system pumps should be made of ______________ to minimize corrosion.

i. A pump made of ______________ may be used in closed loops.

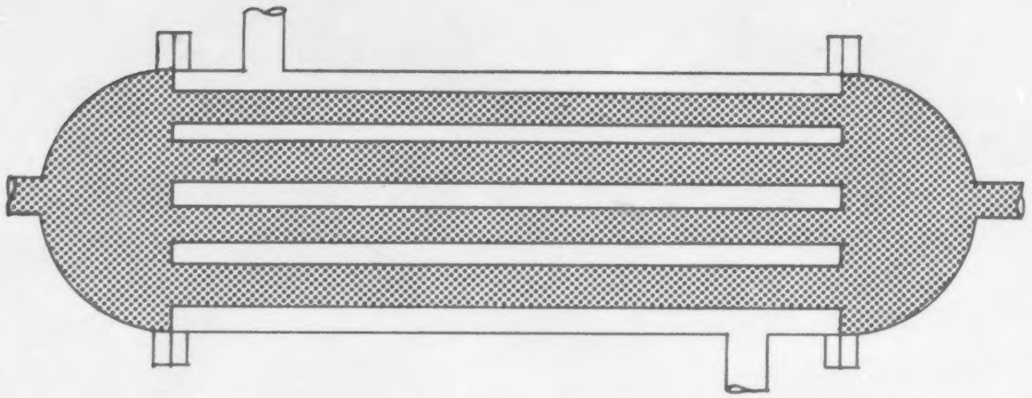
j. How do two-speed pumps improve collector efficiency?

k. What is the purpose of including a heat exchanger between the collector and storage loops of a liquid system?

1. What type of heat exchanger is diagrammed below?

____

Label the direction of fluid flow through the piping and shell.



a. In solar air systems, centrifugal blowers are often used instead of conventional warm air heating blowers because of (increased, decreased) resistance in solar systems.

b. Static pressure is:

c. Velocity pressure is:

d. Total pressure is:

e. For low pressure duct systems ______________ pressure is usually specified for design purposes.

f. As static pressure (increases, decreases) fan capacity decreases.

g. The ______________ point of a system describes the air pressure and rate of air flow at which a fan operates most effieiently. It is identified by the point at which the ______________ curve crosses the ______________ curve.

h. A fan is operating at 400 rpm, delivering 1200 cfm at .20 in WG external static pressure, and requiring a brake horsepower (BHP) of .06. The fan speed is changed to 800 rpm. What is the new

air flow rate:

resistance pressure:

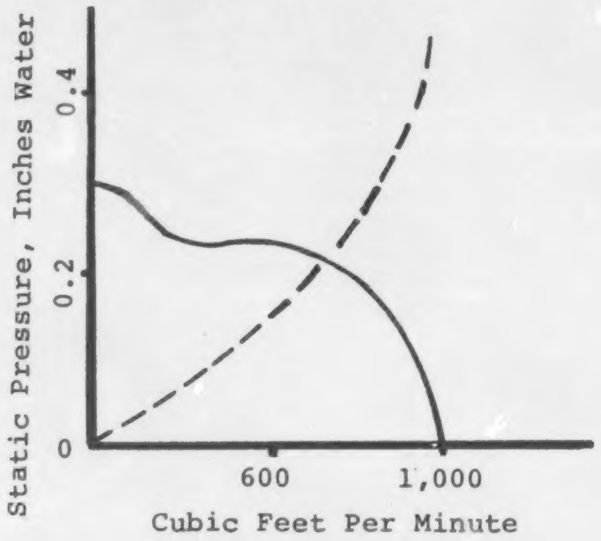
brake horsepower:

i. The resistance pressure of a fan (increases, decreases) with rising air flow rate.

j. The resistance of a duct system (increases, decreases) with rising air flow rate.

k. List factors that can change the duct system curve.

l. Where is the fan balance point in the diagram shown below? Circle it, and describe it in words.



CONTROL FUNCTIONS

BASIC CONTROL STRATEGY

The basic function of the controller in a solar system is to collect as much useful heat as possible and to deliver it when required to meet the demands of the building. The overall efficiency of the total system can be strongly influenced by the controller.

A block diagram of a controller is shown in Figure 1. The three basic components of the controller are the sensor subsystem, the comparator subsystem, and the output subsystem. The function of the sensor subsystem is to measure temperatures and send this information to the comparator subsystem. The comparator subsystem makes the decisions regarding the control of output devices, such as the turning on and off of blowers and pumps and the opening and closing of valves and dampers.

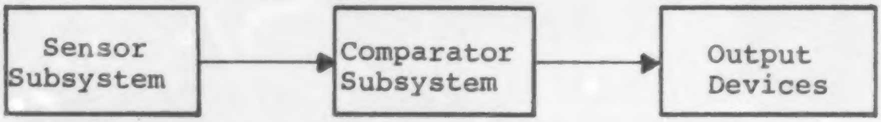


Figure 1

At the present time most commercially available control systems are of the "on-off" type. That is, a pump or blower is either off or on at full capacity. The decision to turn the device on or off is based on temperature differences. For example, consider the schematic representation of a solar system (hydronic type) shown in Figure 2. The temperature sensors are indicated by S1, S2, S3, and S4. S1 measures the temperature of the fluid at the collector (or the temperature of the absorber plate, depending on the type of mounting), S2 measures the temperature of the water in storage, S3 measures the room temperature in the building (there could be several room temperature sensors), and S4 measures the temperature of the water in the preheat tank for service hot water. We shall consider how S1 and S2 are typically used in an "on-off" controller to control the collector pumps, shown as Pump Number 1 and Pump Number 2 in Figure 2. Suppose that the temperature variation throughout a typical day is as shown in Figure 3. The solid curve shows the storage temperature as sensed by S2. As illustrated in Figure 3, the collector temperature will begin to rise in the morning and will exceed the storage temperature at some point. When the collector

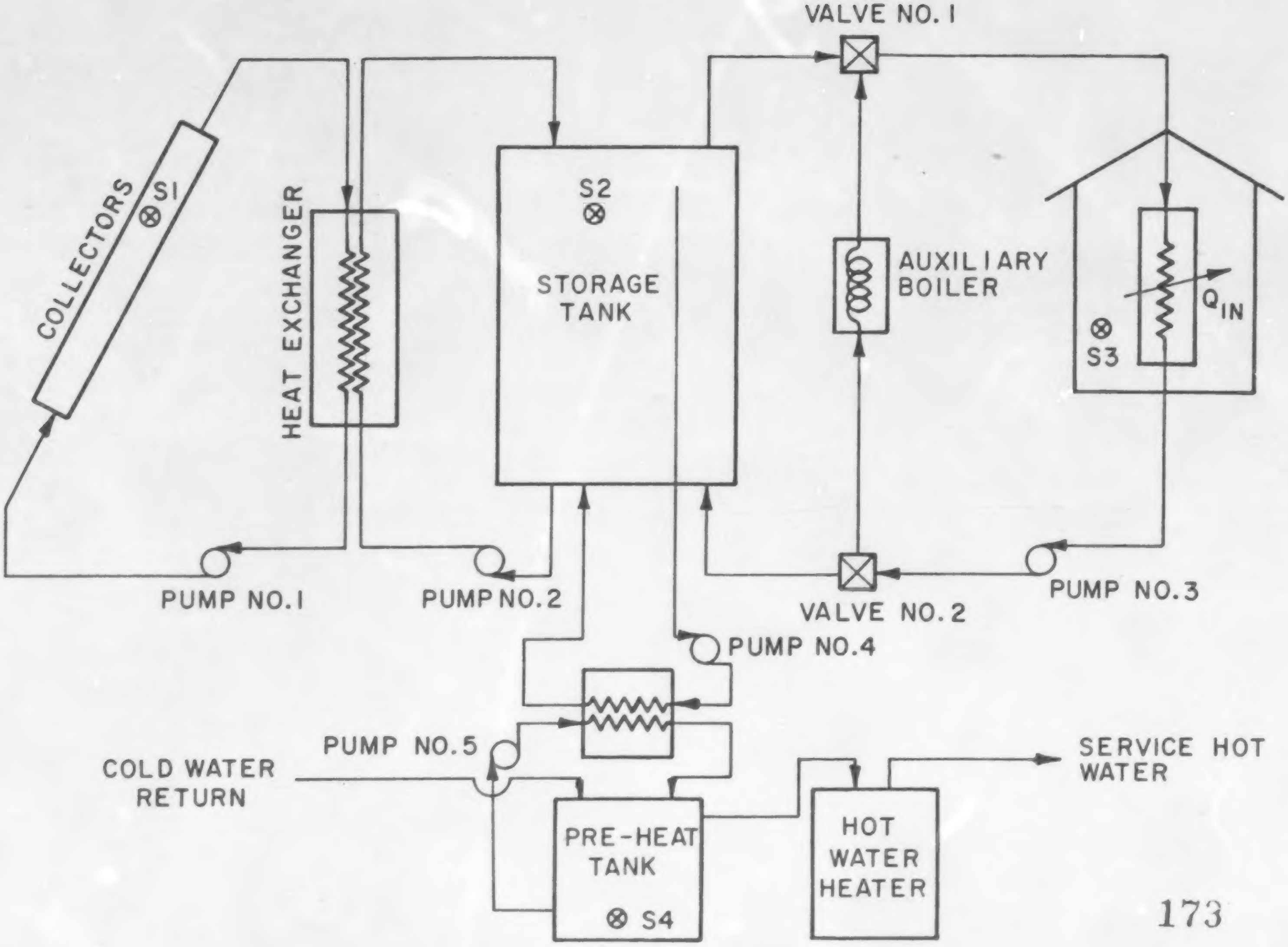

VALVE NO. 1
COLLECTORS
S1
HEAT EXCHANGER
S2
STORAGE TANK
AUXILIARY BOILER
Q_{IN}
S3
PUMP NO. 1
PUMP NO. 2
VALVE NO. 2
PUMP NO. 3
PUMP NO. 4
PUMP NO. 5
COLD WATER RETURN
SERVICE HOT WATER
PRE-HEAT TANK
S4
HOT WATER HEATER

Figure 2

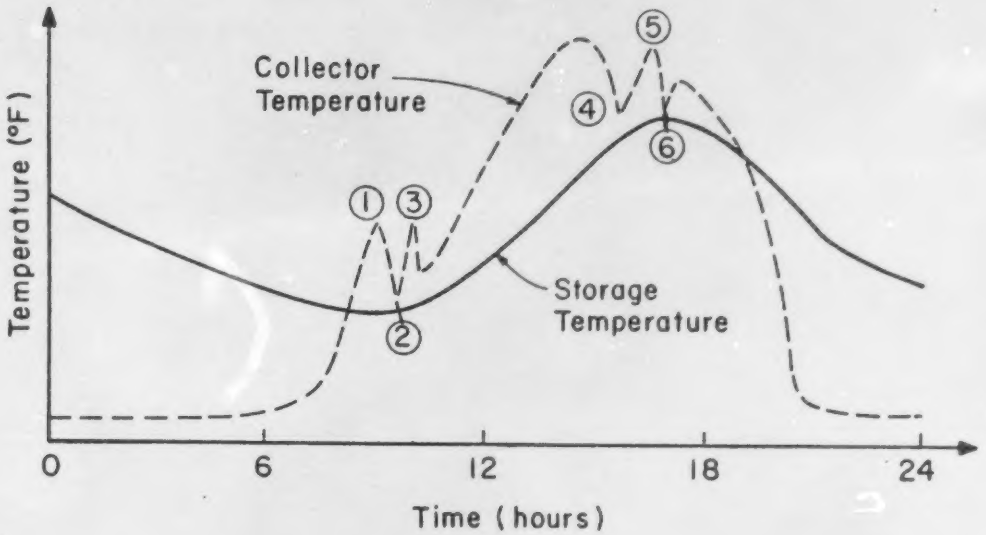


Figure 3

temperature exceeds the storage temperature by some preset amount, T_{ON}, typically about 20° F, the collector/storage pumps will be turned on by the controller. This is indicated by point 1 in Figure 3. This will cause a surge of cooler fluid to circulate through the collectors, thereby lowering the collector temperature, as shown in the figure. If the decrease in collector temperature is great enough to cause the difference between the collector and storage temperatures to drop below another preset value, T_{OFF}, typically about 3° F, the collector/storage pumps will be turned off, as indicated by point 2 in the figure. The temperature of the collector will again increase rather rapidly to point 3 at which time the collector/storage pumps will again be turned on. The amount of cycling of this type should be minimized in order to reduce wear on the pumps, pump motors, and relay contacts (if relays are used). If there is sufficient solar insolation, the collector temperature will continue to increase as illustrated in the figure, and the pumps will remain on until late in the afternoon. When the temperature differential has decreased again to T_{OFF}, the collector/storage pumps will be turned off. This is represented by point 4 on the figure. This will cause the collector temperature to again increase due to the "no-flow" condition. If the temperature differential reaches T_{ON}, the pumps will again be turned on (point 5 in the figure). This will lead to cooling of the collectors (point 6). The collector temperature will start to increase, but if the increase is not large enough, the pumps will remain off.

The sensors that are used in the sensor subsystem are typically thermistors, thermocouples, or transistors. The sensors that are provided with the controller should be used, since the controller is usually calibrated for a particular sensor. This is particularly true if thermistors are used, since the voltage output of the thermistor is a nonlinear function of temperature. Typical circuitry for a single function differential thermostat (controller) is shown in Figure 4.

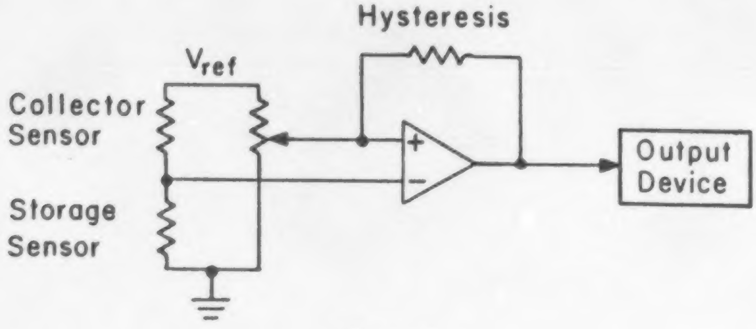


Figure 4

The hysteresis is represented pictorially in Figure 5 and is realized physically by the feedback resistance shown in Figure 4.

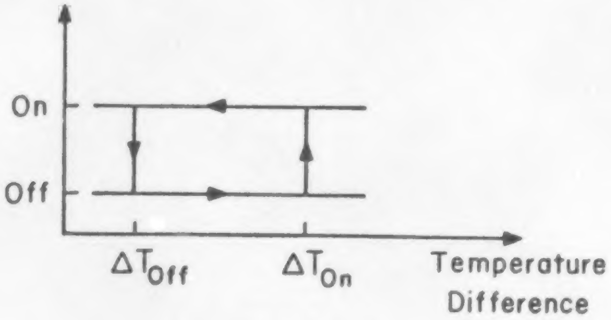


Figure 5

As shown in Figure 5, as the temperature difference increases and eventually reaches the value of T_{ON}, the signal to the output device is such that the device is turned on. If the temperature difference decreases to the point where it is equal to T_{OFF}, the OFF signal will be sent to the output device.

Ratio of Temperature Difference

If the temperature sensor for the collector is located where the sensor is rapidly cooled by the transport fluid, the result can be that the collector pumps will cycle on and off repeatedly. This cycling can also occur if the difference between the temperature to start and to stop the system is not properly selected. The ratio between the on to off temperature differences should be approximately five to seven. In the example given in the preceding paragraphs, the starting temperature difference was 20° F and the stopping temperature difference was 3° F. The ratio is slightly less than seven. A larger value for this ratio will reduce the total energy collected by the system, while a value smaller than five could cause cycling.

Freezing Protection

Some controllers are designed to incorporate an aquastat to compare the temperature of the transport medium with some preset temperature such as the freezing temperature of water. If the temperature of the fluid in the collector approaches this preset temperature, the pumps are automatically started to circulate the fluid or to heat the fluid from storage in order to prevent freezing. This is not a recommended protection measure against freezing, because if there is a power failure during cold weather, the pumps will not operate and the collectors can freeze. It is preferred to use an antifreeze solution in the collector loop.

Two-Speed Pump

A two-speed pump may be considered as a possible way to regulate the temperature rise in the collector to improve collection efficiency. By changing to a slower flow rate during periods of low solar insolation, the system will collect heat at useful temperatures, whereas with a high flow rate, the temperature of the fluid at the collector outlet would be low and the control would stop the collector pump. When the solar radiation intensity is high, the flow rate can be increased. The fluid temperature would be reduced because of greater flow, and the collector will operate more efficiently.

a. The three basic components of a controller are the __________ subsystem, the ______________ subsystem and the ______________ subsystem.

b. The ______________ subsystem measures temperatures.

c. The ______________ subsystem looks at temperature differences.

d. The ______________ subsystem turns on or off blowers, pumps, valves, or dampers.

e. The decision to turn on or off an output device is based on ______________.

f. In a space heating system, sensors are installed the following three locations: ______________, ______________, ______________.

g. A temperature difference of about ______________ degrees F, usually turns the collector/storage pumps.

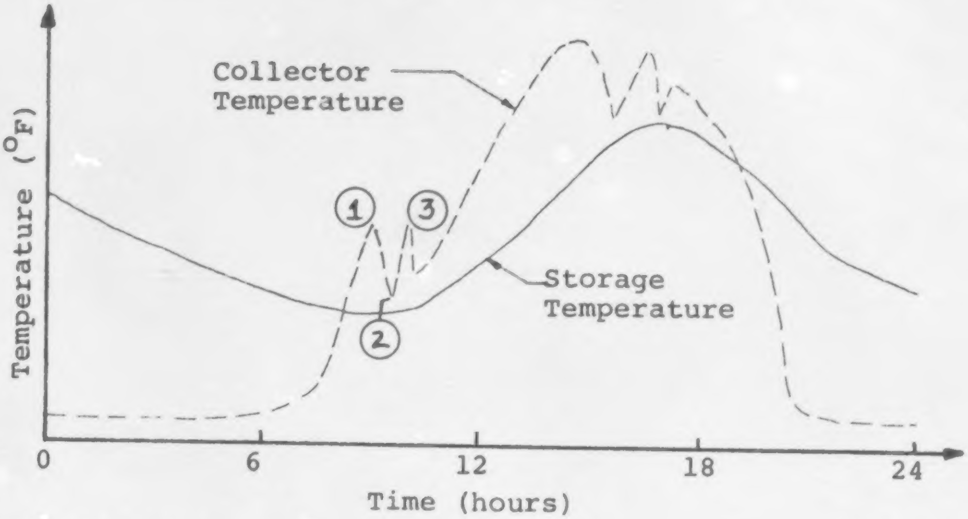
h. The collector/storage pumps usually turn on when the collector temperature exceeds the storage temperature by about ______________ degrees F.

i. Three types of sensors used in solar systems are ____________, ______________, and ______________.

j. What is done to avoid on-off pump cycling, and consequent excessive wear on the pump?

k. Turning on pumps to circulate water might be used to avoid freezing. Why is this not recommended?

1. Consider the following figure: (similar to Figure 11-3)



The solid line represents storage temperature. The dashed line represents collector temperature. Describe completely what happened to the temperatures and in the control system at points 1, 2 and 3.

a. The ______________ stage of a two-stage thermostat calls for solar heat, while the ______________ stage turns on the conventional heating system.

b. A differential temperature controller measures ______________ ____.

c. A ______________ differential controller varies pump speed as a function of the size of the temperature difference between collector and storage tank.

d. A ______________ converts changes in pressure or temperature into electrical or mechanical action.

e. A ______________ sensor consists of metal strips which expand and bend at different rates per degree rise in temperature.

f. A ______________ sensor contains a fluid which expands when heated to turn on the output mechanism.

g. Electrical current flow varies in proportion to temperature in a sensor called a ______________. The current change can be used to ____________________.

h. ______________ sensors can be located far from the controlled device.

i. The ability of a sensor to react to temperature change is called the ______________.

j. To detect collector overheating, a sensor is placed near the ______________.

k. Two reasons for placing a thermister in a bulb well in a liquid system are:

   1.

   2.

l. In liquid systems, ______________ are used to start, stop, and divert fluid flow.

m. A ______________ converts live voltage to lower voltage- Typically, solar control devices operate at ______________ volts.

n. In air systems, ______________ are used to start, stop, and divert fluid flow.

o. A low voltage thermostat is often used to activate a ______________, causing a higher voltage output device to operate.

ASSIGNMENT SHEET SB-5-10

a. Indicate the purpose and location of each of the following hydronics specialty items.

	Location	Purpose
expansion tank		
air vent		
check valve		
vacuum breaker		
pressure relief valve		
balancing valve		
pressure reducing valve		
air eliminator		
dielectric union		

b. When must collector loop filling be done manually?

SOLAR HEATING SYSTEMS CURRICULUM
UNIT LISTING

PHASE A: BASIC UNDERSTANDING

Unit	Task
SA-1	Explain the value of solar energy and principles of solar radiation.
SA-2	Describe basic solar system components and their functions.

PHASE B: DESIGN

Unit	Task
SB-1	Recommend non-solar energy conservation measures.
SB-2	Select passive solar approaches for new construction.
SB-3	Recommend collectors.
SB-4	Recommend and site the thermal storage unit.
SB-5	Recommend control devices.
SB-6	Recognize and describe modes of solar system operation.
SB-7	Calculate heat load for space or domestic hot water heating.
SB-8	Size solar system components.
SB-9	Perform a solar system economic analysis.
SB-10	Recommend a domestic hot water system.

PHASE C: INSTALLATION

Unit	Task
SC-1	Recommend correct thermal mass for direct gain system; fabricate and install modular wall units for passive solar.
SC-2	Schedule solar installation.
SC-3	Install a liquid storage tank.
SC-4	Site and mount collectors.
SC-5	Install liquid collectors and outside plumbing.
SC-6	Install inside plumbing for collector load side loops.
SC-7	Install controls and wiring.
SC-8	Start up system.

PHASE D MAINTENANCE

Unit	Task
SD-1	Maintain the solar system.
SD-2	Troubleshoot solar system problems

MAJOR BLOCK Solar Systems (Phase B: Design) **NAME**

TASK Recognize and describe modes of solar system operation

UNIT SB-6 **TIME** (est.) ______ (act.) ______

OBJECTIVE(S) The student will be able to:

(1) List the operating modes of liquid and air systems

(2) Recognize conditions appropriate for each operating mode

(3) Diagram and describe proper system operation for each operating mode

START → A-1 → W-1 → L-1 → C-1 → W-2 → L-2 → W-3 → L-3 → C-2 → C-3

WRITTEN ASSIGNMENT(S)		AUDIOVISUAL(S)	
W-1	Assignment SB-6-1	A-1	Slide Set SB-6-1
W-2	Assignment SB-6-3	A-2	
W-3	Assignment SB-6-5	A-3	
W-4		A-4	
W-5		A-5	
W-6		A-6	
W-7		A-7	

LABORATORY ASSIGNMENT(S)		CHECKPOINT(S)	
L-1	Assignment SB-6-2	C-1	Observation
L-2	Assignment SB-6-4	C-2	Observation
L-3	Assignment SB-6-6	C-3	Test (written)
L-4		C-4	
L-5		C-5	
L-6		C-6	
L-7		C-7	
L-8		C-8	
L-9		C-9	

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1979

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ACTIVITY SEQUENCE SHEET

Activity	Flow Chart Number	Description of Activity
Slide Set SB-6-1	A-1	View slide set SB-6-1.
Assignment SB-6-1	W-1	Read Lennox Solar Manual, Controls, p. 5-17.
Assignment SB-6-2	L-1	Do activity described on Assignment Sheet SB-6-2.
Observation	C-1	Observation by teacher of completed Assignment Sheet SB-6-2.
Assignment SB-6-3	W-2	Read Fundamentals, page 7-6 to 7-8 (Section on "Heating with a hydronic solar heating system").
Assignment SB-6-4	L-2	Do study questions on Assignment Sheet SB-6-4.
Assignment SB-6-5	W-3	Read Fundamentals, page 7-1 to 7-4 (up to "Domestic water heating").
Assignment SB-6-6	L-3	Do activity described on Assignment Sheet SB-6-6.
Observation	C-2	Observation by teacher of completed Assignment Sheet SB-6-6.
Test	C-3	Written.

LIQUID SYSTEM OPERATION

On the following pages are copies of a schematic diagram of a liquid solar system. Label the diagram so that it illustrates the mode of operation indicated at the top of the diagram. Indicate which solar system components are involved and how they are functioning. Your labeled diagram should provide answers to the following questions:

a. Which system component is the major source of heat?

b. Which pumps are operating?

c. Is the auxiliary unit fan on or off?

d. Is the auxiliary heat on or off?

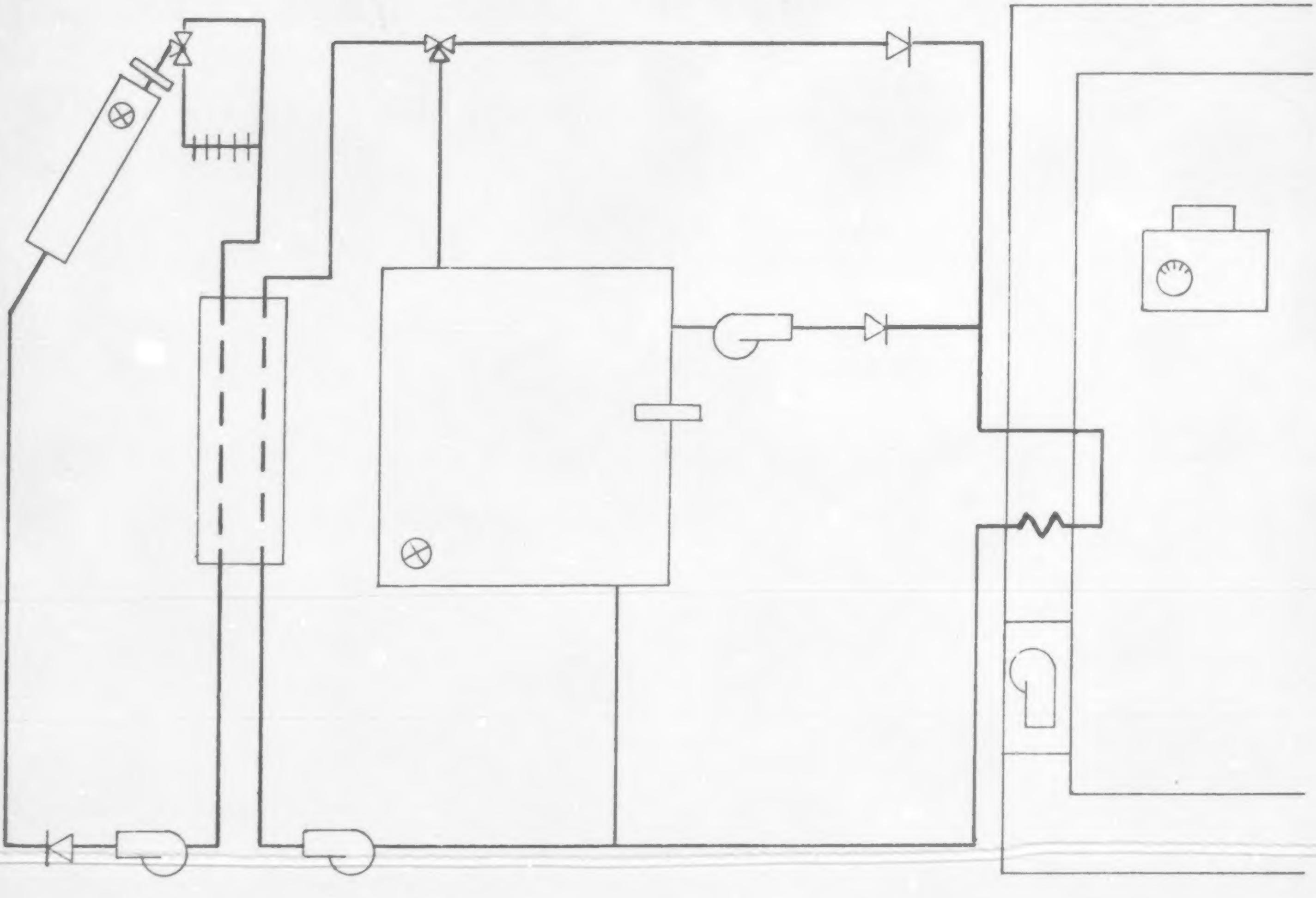
e. Which temperature sensors are involved in initiating the operating mode?

f. How are diverting valves 1 and 2 positioned?

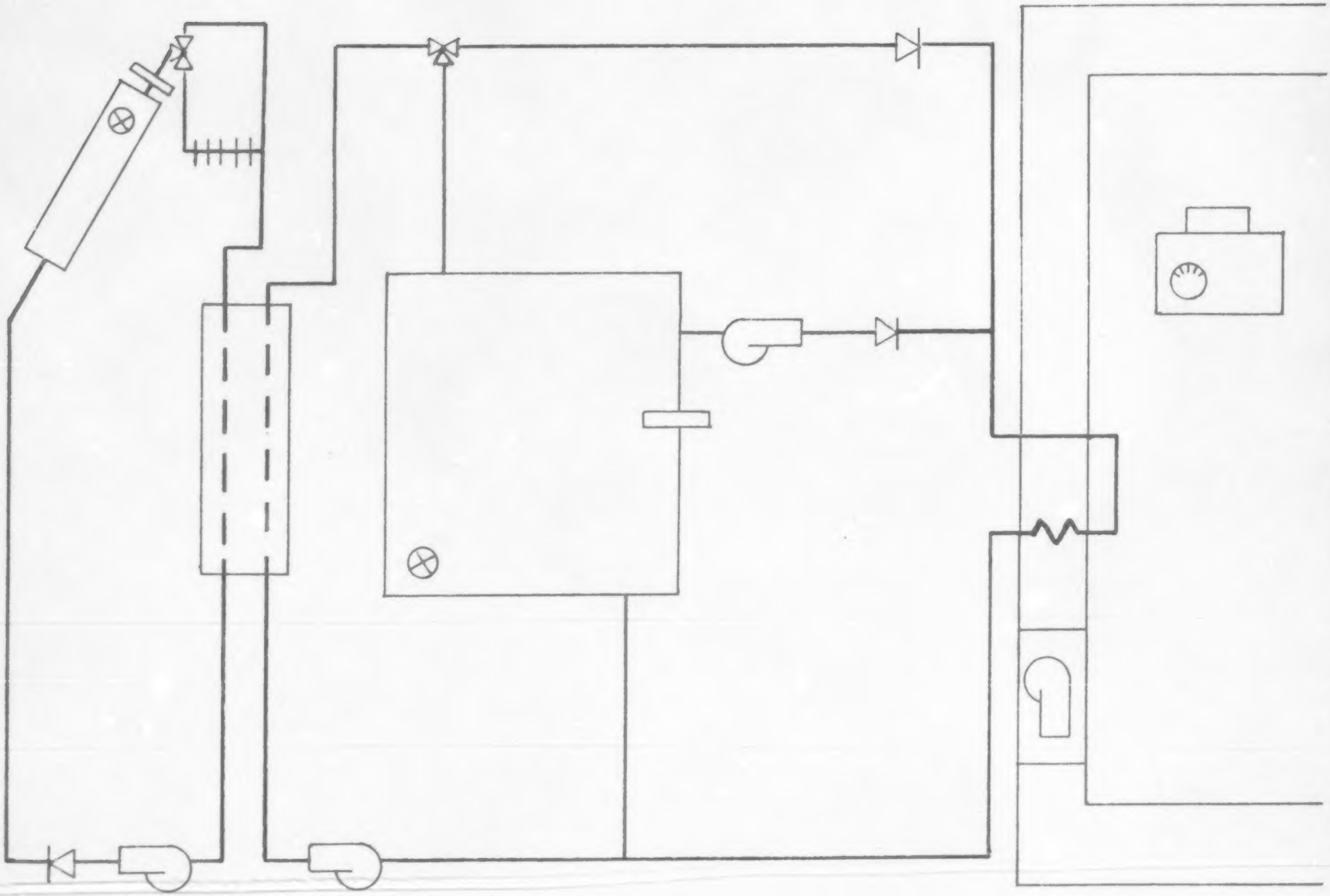
g. Which stage of the indoor thermostat is in control?

h. In what direction, if any, is fluid flowing in the storage loop? collector loop? load loop? duct system?

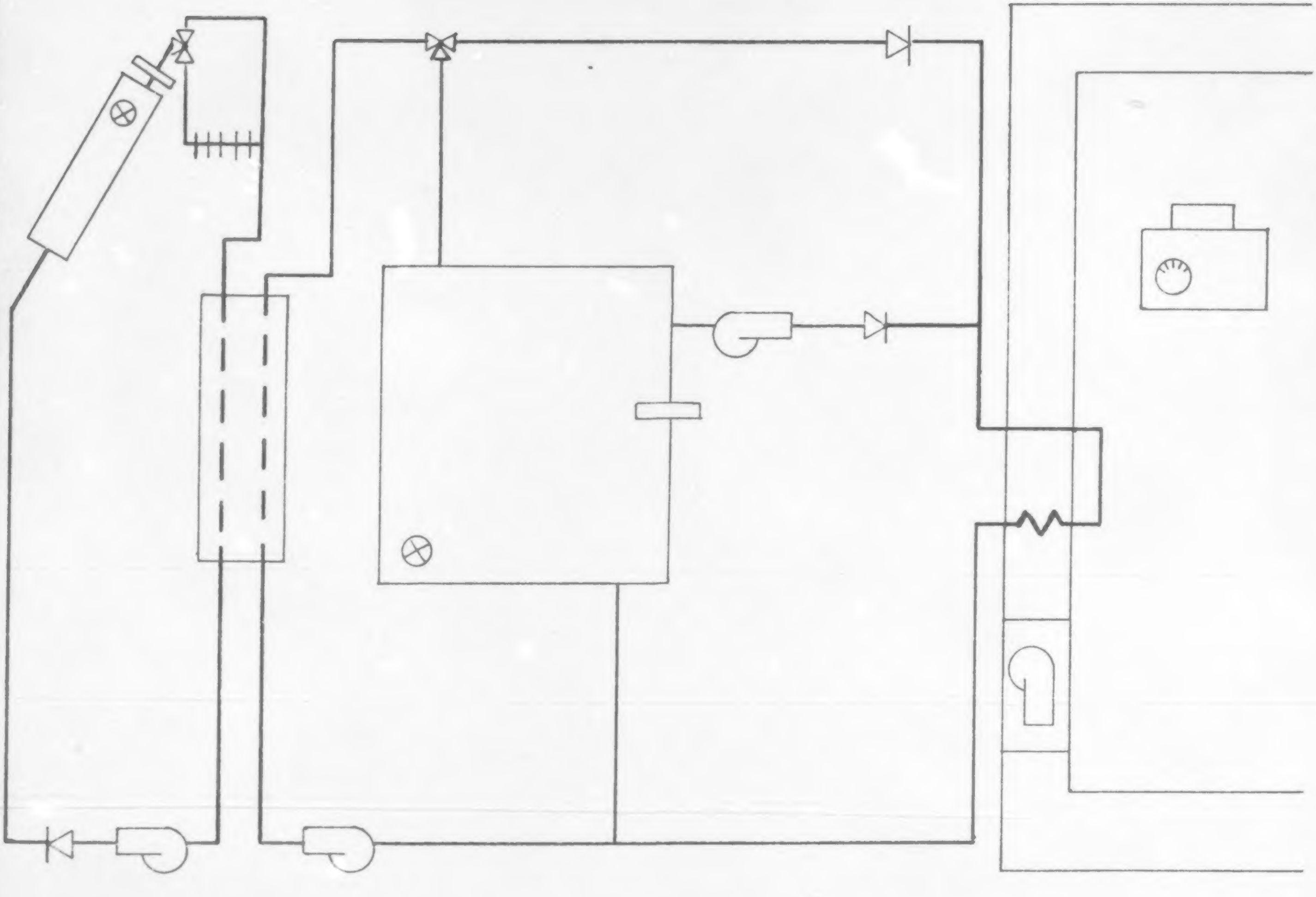
Mode of Operation: Heating from Collectors



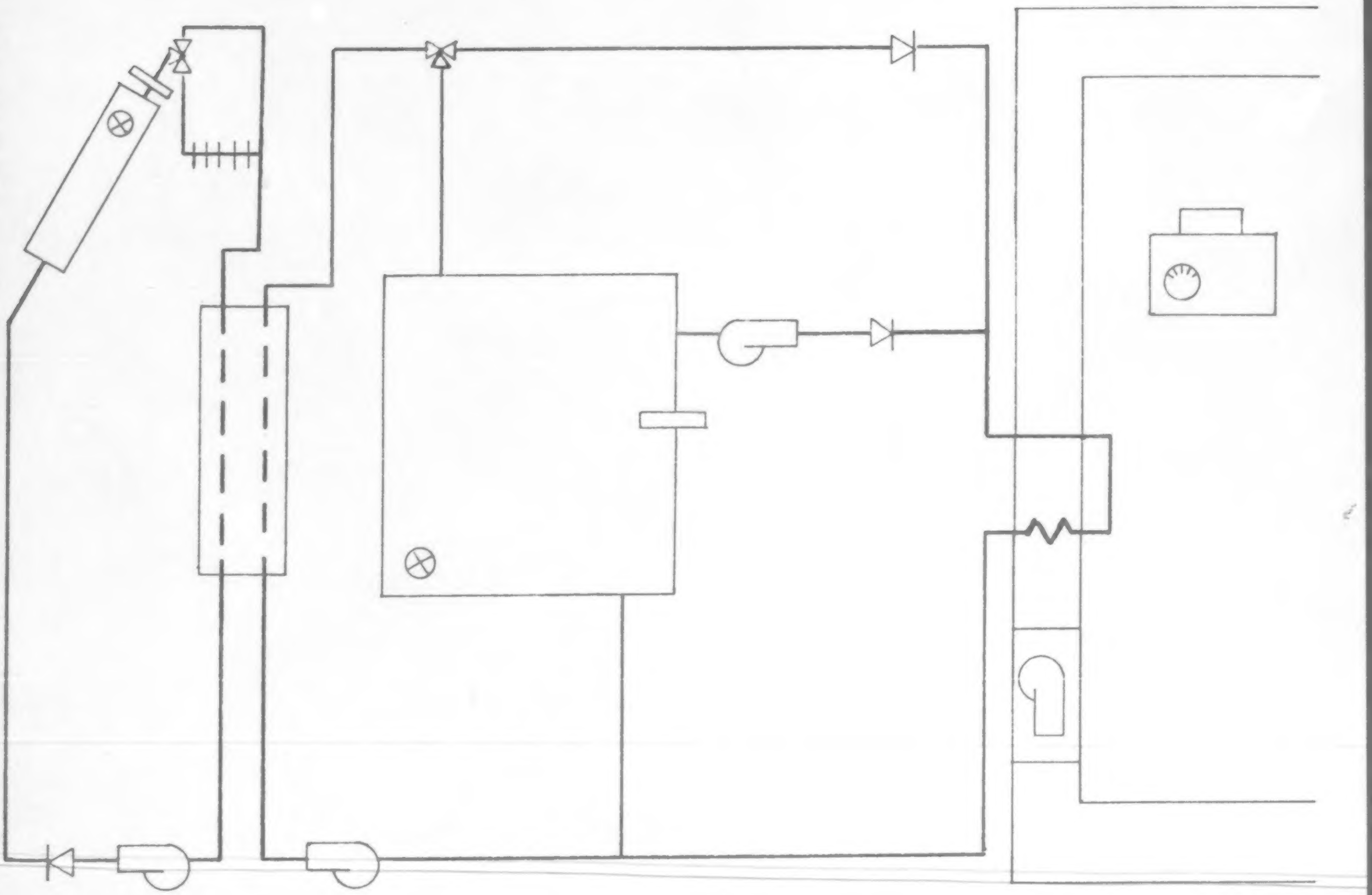
Mode of Operation: Heating from Storage



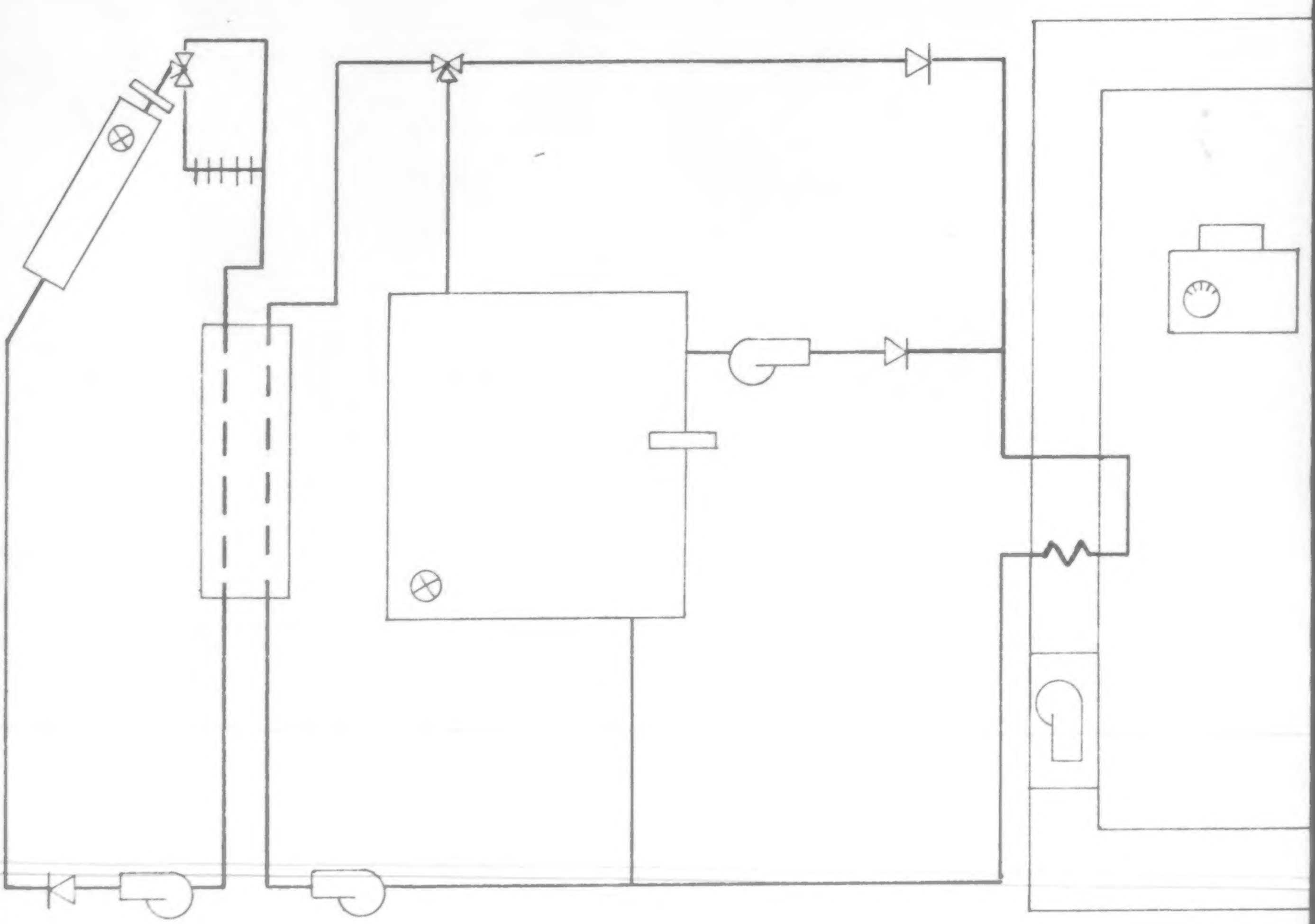
Mode of Operation: Heating from Auxiliary Unit



Mode of Operation: Storing Heat



Mode of Operation: Purging heat



ASSIGNMENT SHEET SB-6-4

LIQUID SYSTEM OPERATION

a. What is the consequence for system operation of not being able to provide space heating directly from the collector?

b. How is the temperature of the solar heated liquid used for space heating related to the type of space heating system that can be used?

c. If a heat pump is to be used for auxiliary heating, where should its refrigerant coil be placed relative to the duct coil?

AIR SYSTEM OPERATION

On the following pages are copies of a schematic diagram of an air solar system. Label the diagram so that it illustrates the mode of operation indicated at the top of the diagram. Indicate which solar system components are involved and how they are functioning. Your labeled diagram should provide answers to the following questions:

a. Which system component is the major source of heat?

b. Which fans are operating?

c. Is the auxiliary unit on or off?

d. Is the auxiliary heat on or off?

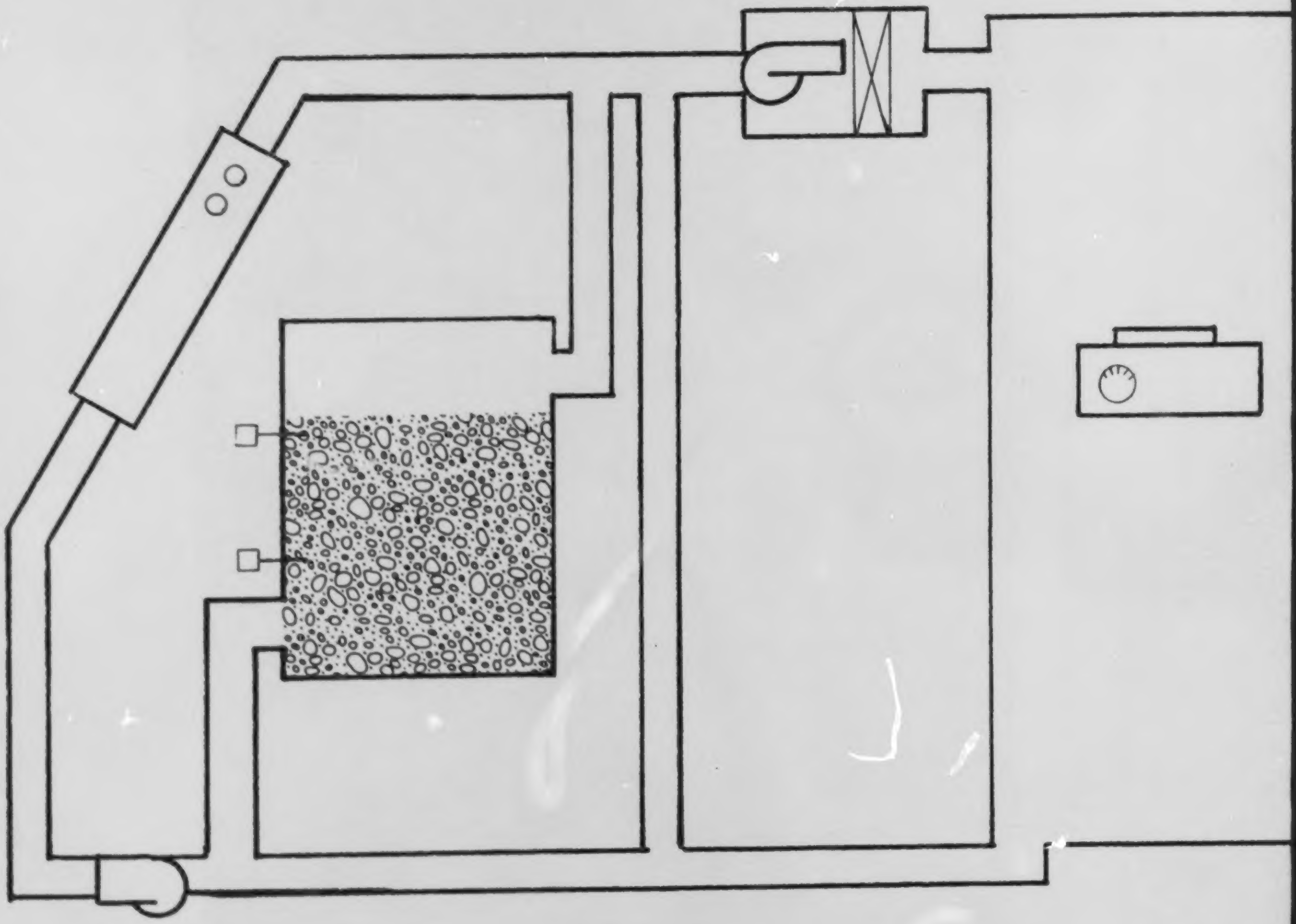
e. Which temperature sensors and temperature comparisons are involved in initiating the operating mode?

f. How are the dampers positioned?

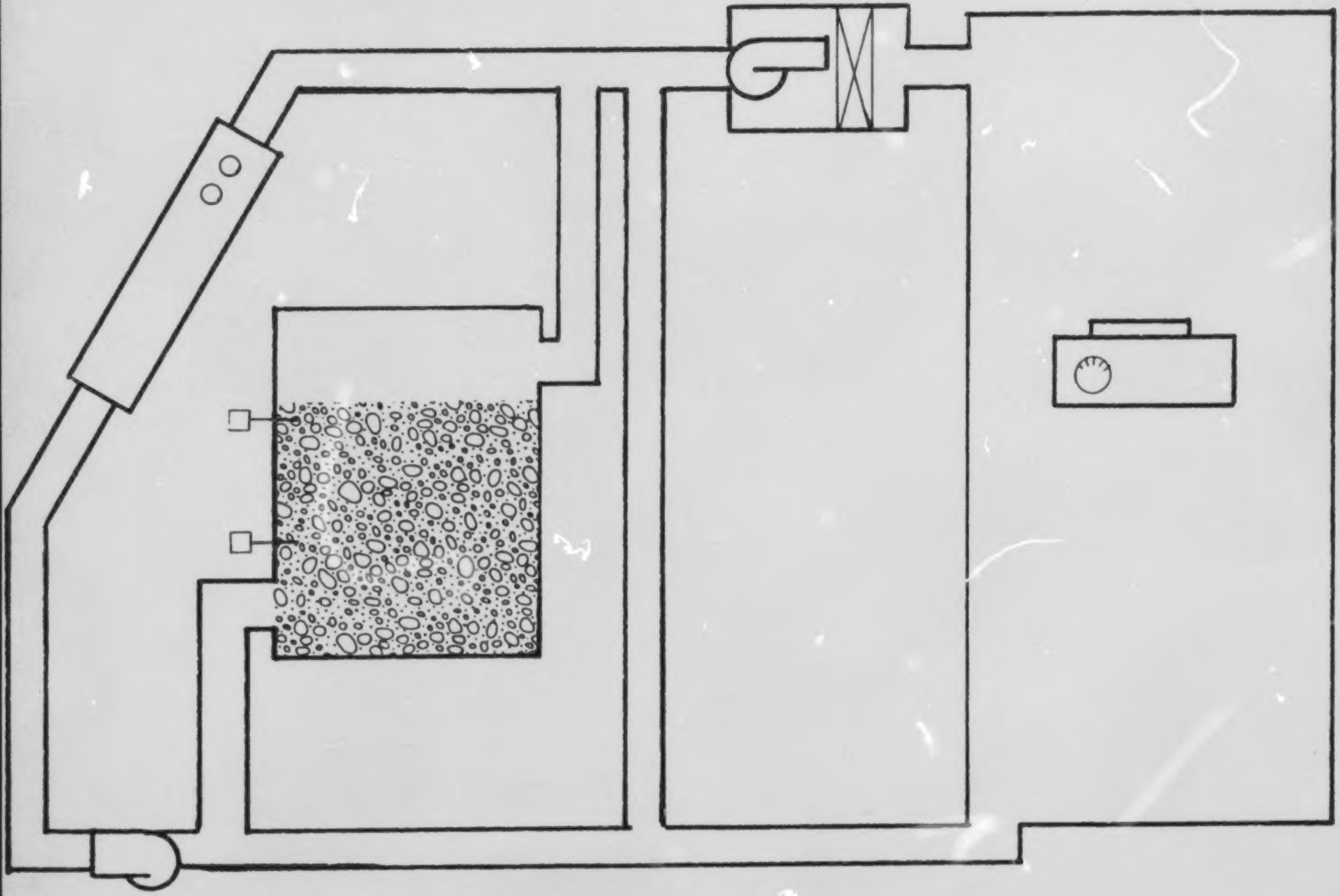
g. Which stage of the indoor thermostat is in control?

h. In what direction, if any, is fluid flowing in the collector loop? the storage loop? the duct system?

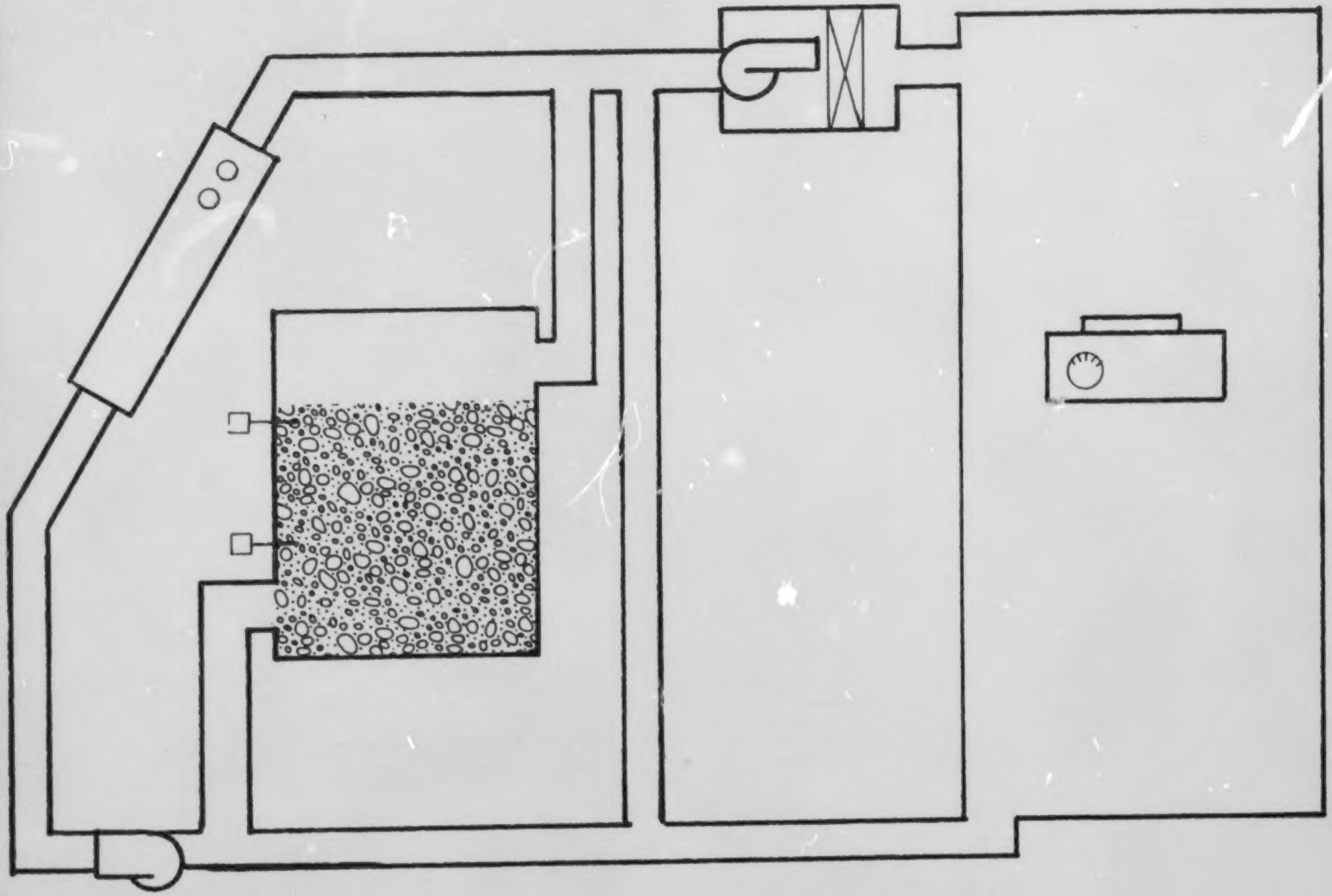
Mode of Operation: Heating from Collectors



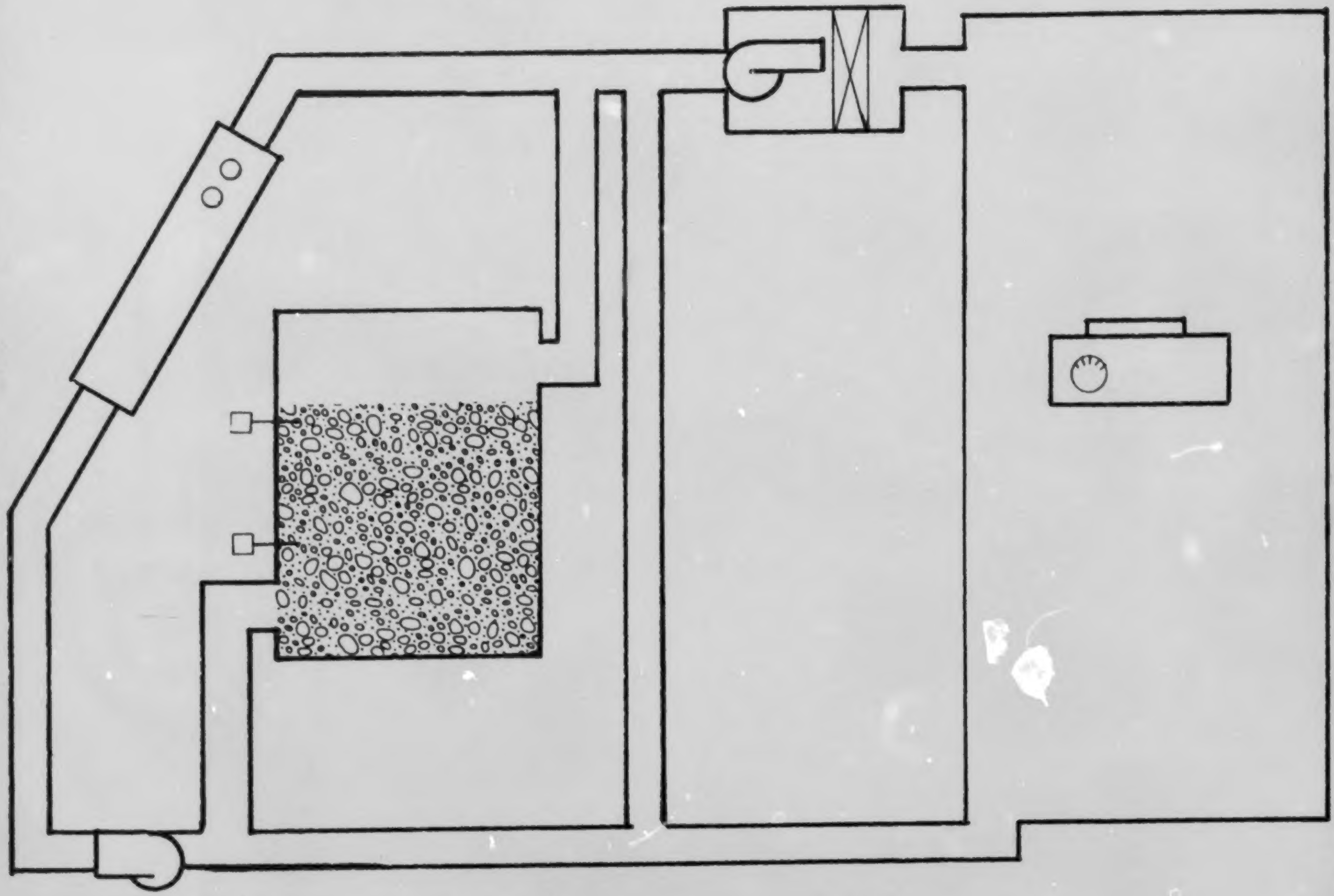
Mode of Operation: Heating from Storage



Mode of Operation: Storing Heat



Mode of Operation: Heating from auxiliary unit



SOLAR HEATING SYSTEMS CURRICULUM
UNIT LISTING

PHASE A: BASIC UNDERSTANDING

Unit	Task
SA-1	Explain the value of solar energy and principles of solar radiation.
SA-2	Describe basic solar system components and their functions.

PHASE B: DESIGN

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SB-1	Recommend non-solar energy conservation measures.
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SC-8	Start up system.

PHASE D MAINTENANCE

Unit	Task
SD-1	Maintain the solar system.
SD-2	Troubleshoot solar system problems

MAJOR BLOCK Solar Systems (Phase B: Design) **NAME** ____________

TASK Calculating heat load for space or domestic hot water heating

UNIT SB-7 **TIME** (est.) ________ (act.) ______

OBJECTIVE(S) The student will be able to:

1) calculate rate of heat loss for buildings
2) calculate daily, monthly and annual space heating loads
3) calculate domestic hot water heating loads

START → W-1 → L-1 → C-1 → W-2 → L-2 → W-3 → L-3 → C-2 →
W-4 → L-4 → C-3 → W-5 → L-5 → W-6 → W-7 → C-4 → L-6 → C-5 →
C-6 → ☐ → ☐ → ☐ → ☐ → ☐ → ☐ → ☐ → ☐ → ☐

WRITTEN ASSIGNMENT(S)		**AUDIOVISUAL(S)**	
W-1	Information Sheet SB-7-1	A-1	
W-2	Information Sheet SB-7-2	A-2	
W-3	Information Sheet SB-7-3	A-3	
W-4	Information Sheet SB-7-4	A-4	
W-5	Information Sheet SB-7-5	A-5	
W-6	Information Sheet SB-7-6	A-6	
W-7	Information Sheet SB-7-7	A-7	

LABORATORY ASSIGNMENT(S)		**CHECKPOINT(S)**	
L-1	Assignment Sheet SB-7-1	C-1	Progress Check (self-graded quiz)
L-2	Assignment Sheet SB-7-2	C-2	Progress Check (written quiz)
L-3	Assignment Sheet SB-7-3	C-3	Progress Check (written quiz)
L-4	Assignment Sheet SB-7-4	C-4	Demonstration
L-5	Assignment Sheet SB-7-5	C-5	Observation
L-6	Assignment Sheet SB-7-6	C-6	Test (written)
L-7		C-7	
L-8		C-8	
L-9		C-9	

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ACTIVITY SEQUENCE SHEET

Activity	Flow Chart Number	Description of Activity
Information Sheet SB-7-1	W-1	Read Information Sheet SB-7-1. Be able to use the tabled information and perform problems similar to the example given.
Assignment Sheet SB-7-1	L-1	Do problems on Assignment Sheet SB-7-1
Progress Check	C-1	Self-graded quiz.
Information Sheet SB-7-2	W-2	Read Information Sheet SB-7-2.
Assignment Sheet SB-7-2	L-2	Do problems on Assignment Sheet SB-7-2.
Information Sheet SB-7-3	W-3	Read Information Sheet SB-7-3.
Assignment Sheet SB-7-3	L-3	Do problems on Assignment Sheet SB-7-3.
Progress Check	C-2	Written quiz.
Information Sheet SB-7-4	W-4	Read Information Sheet SB-7-4.
Assignment Sheet SB-7-4	L-4	Do problems on Assignment Sheet SB-7-4.
Progress Check	C-3	Written quiz.
Information Sheet SB-7-5	W-5	Read Information Sheet SB-7-5.
Assignment Sheet SB-7-5	L-5	Do problems on Assignment Sheet SB-7-5.
Information Sheet SB-7-6	W-6	Read Information Sheet SB-7-6.
Information Sheet SB-7-7	W-7	Go over problem on Information Sheet SB-7-7.

Demonstration	C-4	Demonstration.
Assignment Sheet SB-7-6	L-6	Do problem on Assignment Sheet SB-7-6.
Observation	C-5	Observation by teacher.
Test	C-6	Written unit test.

CALCULATING BUILDING HEAT LOAD: BASIC TERMS

Calculating building heat load is one of the most important steps in designing a residential solar system. The building heat load determines the sizing of solar system components, and in particular, the number of solar collectors. Correct building heat load calculations contribute to the design of a home which is comfortable, efficient, and of minimum cost. Incorrect calculation may produce a poorly heated, overly expensive solar home.

Resistance to Heat Flow (R)

In calculating heat load, a variety of factors must be considered. Of particular interest is the extent to which the construction materials of the house either resist or transmit heat. A material's resistance to heat flow is symbolized by R. The higher the R value, the greater the resistance to heat loss. R values are often used in specifying standards for ceiling materials or for insulation, and increase with the thickness of the material. For example, 2-inch insulation has an R value of 7, while 3-inch insulation has an R value of 11. (See Table 1).

R values are additive, so the total heat resistance of a wall consisting of several layers can be calculated by adding the R values of each of the contributing layers. For example, consider a wall consisting of wood siding, sheathing, insulation, and gypsum wall board. It is necessary to recognize that thin films of air on the outside of the wall, and on the inside, also contribute to heat resistance. The total R value of the wall may be calculated by adding the R values of the layers which contribute to heat resistance.

	R
Outside air film (15 mph wind, winter)	.17
Siding wood (½" x 8", lapped)	.81
Sheathing (½" regular)	1.32
Insulation batt (3" to 3½")	11.00
Gypsum wall board (½")	.45
Inside surface (winter)	.68
Total wall heat resistance (R_T or ΣR) =	14.43

Coefficient of Heat Transmission (U)

The formulas for building heat load calculations make direct use of coefficients of heat transmission, or U values, rather than R values. U is the number of Btu's that will pass through one square foot of a material of known thickness in one hour, when the temperature on the two sides of the material differs by 1° F. The higher the U value, the greater the rate of heat transmission. For example, single pane glass has a U value of 1.13 $Btu/hr/ft^2/^{\circ}F$, while double pane glass with a ¼-inch air space has a U value of .65 $Btu/hr/ft^2/^{\circ}F$. (See Table 1). This difference in U value represents the fact that single pane glass transmits more heat than double pane glass.

The U value of a multi-layer materials, such as a wall, can be calculated from the R values by taking advantage of the fact that

$$U = \frac{1}{R_T}$$

or

$$U = \frac{1}{\Sigma R}\text{, where } \Sigma \text{ is the symbol for sum.}$$

Consider the sample wall analyzed earlier for heat resistance. The R_T value for the wall was determined to be 14.43. The U value of the wall can be calculated as follows:

$$U = \frac{1}{R_T}$$

$$U = \frac{1}{14.43}$$

$$U = .07$$

We can calculate the U value of any material, either a wall, ceiling, or otherwise, by performing the following two simple steps:

1) determine the total heat resistance (R_T) value of the material by summing the R values of the material layers
2) take the reciprocal of R_T.

203

Rate of Heat Conduction Through a Unit Area of Unit Thickness (k)

A final useful term is k, the rate of heat conduction through a unit area of surface of a material for a unit thickness of that material. The units of k are described in Btu/in/hr/ft^2/°F. For example, the k value of stucco is 5. (See Table 1). This means that for stucco material 1 ft x 1 ft x 1 in, and differing in temperature by 1° F between sides, 5 Btu pass through the material during each hour. K values may be used to calculate R values by use of the following formula:

$$R = \frac{1}{k} \times \text{(thickness of the material)}$$

To calculate the R value of 6 inches of stucco, the formula may be applied as follows:

$$R = \frac{1}{k} \times \text{(thickness of the material)}$$

$$R = \frac{1}{5} \times 6''$$

$$R = \frac{6}{5} = 1.2$$

The coefficient of heat transmission (U) for a 6-inch solid stucco wall can be calculated as follows:

$$U = \frac{1}{R_T}$$

$$U = \frac{1}{1.2}$$

$$U = .83$$

TABLE 1

Values of R, U, and 1/k for Some Structural and Finish Materials, Glass, Doors, Insulation, Air Spaces, and Surface Air Films†

Materials	1/k	R	U
Wood bevel siding, .5 x 8, lapped		0.81	
Wood siding shingles, 16" x 7.5" exposure		0.87	
Asbestos-cement shingles		0.21	
Stucco	0.20		
Building paper		0.06	
½" nail-base insulation board sheathing		1.14	
Insulation board sheathing, regular density	2.63		
Plywood	1.24		
¼" hardboard		0.18	
Softwood board	1.25		
Concrete blocks, 3 oval cores			
Cinder 4" thick		1.11	
Aggregate 12" thick		1.89	
8" thick		1.72	
Sand and gravel aggregate, 8" thick		1.11	
Lightweight aggregate, 8" thick		2.00	
Concrete blocks, 2 rectangular cores			
Sand and gravel aggregate, 8" thick		1.04	
Lightweight aggregate, 8" thick		2.18	
Common brick	0.20		
Face brick	0.11		
Sand-and-gravel concrete	0.08		
Gypsumboard (plasterboard)	0.90		
.5" lighweight-aggregate gypsum plaster		0.32	
25/32" hardwood finish flooring		0.68	
Asphalt, linoleum, vinyl, or rubber floor tile		0.05	
Carpet and fibrous pad		2.08	
Carpet and foam rubber pad		1.23	
Asphalt roof shingles		0.44	
Wood roof shingles		0.94	
3/8" built-up roof		0.33	
Basement floor below grade			0.06
Glass			
Single			1.13
Double ¼" air space			0.65
½" air space			0.58
Triple ¼" air spaces			0.47
½" air spaces			0.36
Storm windows (¼" air space)			0.56

†From ASHRAE Handbook of Fundamentals.

TABLE 1 (Continued)†

Solid Wood Slab Door U Values:		No Storm Door	Storm Door	
			Wood	Metal
	1.00" thick	0.64	0.30	0.39
	1.25" thick	0.55	0.28	0.34
	1.50" thick	0.49	0.27	0.33
	2.20" thick	0.43	0.24	0.29

Insulation:		1/k	R	U
	0" thick		0	
	2.0-2.75" thick	3.58	7	
	3.0-3.5" thick	3.58	11	
	3.5-3.625" thick	3.58	13	
	5.25-6.5" thick	3.58	19	
	6.0-7.0" thick	3.58	22	

	R	U
Approximate U values for ceiling, walls, and floors (other than concrete slabs) with given insulation (R value). If heating unit is in the basement and if ducts or pipes are uninsulated, no floor loss calculation is necessary. For floors over unheated basements, use 1/3 of the approximate U value given or 1/3 of the calculated U value. For floors over unvented crawlspaces with insulated crawlspace walls, use 1/2 of the approximate U value given or 1/2 of the calculated U value. For floors over vented crawl spaces or other open spaces, use the approximate U value given or the calculated U value. Use of the approximate U values given here for a given R value will usually result in a higher heat load than will actually be the case.	0	0.28*
	7	0.11
	11	0.08
	13	0.07
	19	0.05
	22	0.045

		R	U
Concrete Slab Floors: Use linear feet of exposed length of slab edge in place of A:h=U (lin. ft) ΔT			
	1" x 24" insulation		0.21
	1" x 12" insulation		0.46
	No insulation		0.81

			R	U
Air Spaces (3/4")	Heat Flow Up	Non-reflective	0.87	
		Reflective, 1 surface**	2.23	
	Heat Flow Down or horizontal	Non-reflective	1.01	
		Reflective, 1 surface**	3.50	

*When R=O, actual U values may range from 0.2 to 0.5.

**The addition of a second reflective surface facing the first reflective surface increases the thermal resistance values of an air space only 4 to 7%.

†From ASHRAE Handbook of Fundamentals.

TABLE I (Continued)†

			R	U
Surface Air Films	Heat Flow Up	Non-reflective	0.61	
		Reflective	1.32	
	Heat Flow Down	Non-reflective	0.92	
		Reflective	4.55	
	Heat Flow Horizontal	Through vertical surface, non-reflective	0.68	
	Outside (15 mph wind)		0.17	

†From ASHRAE Handbook of Fundamentals.

EXAMPLE 1

In this example, calculations are made to determine the U value of an exterior wall. The 1/k, R, and U values are given in Table 1.

	Thickness inches	1/k	R Value	
			Uninsulated	Insulated
Outside surface air film (15 mph)			0.17	0.17
Wood bevel siding, 1/2 x 8, lapped			0.81	0.81
Ins. Bd. sheathing, reg. density	.5	2.63	1.32	1.32
Air space	3.5		1.01	
Insulation	3.5		0.00	11
Gypsumboard	.5	0.90	0.45	0.45
Inside surface air film			0.68	0.68
Totals (Σ)			4.44	14.43

For the uninsulated wall, $U = 1/\Sigma R = 1/4.44 = 0.23$ Btu/(hr)(ft^2)($^{\circ}$F), which is lower than the approximate value of 0.28 given in Table I. For the insulated wall, $U = 1/\Sigma R = 1/14.34 = 0.07$ Btu/(hr)(ft^2)($^{\circ}$F), which compares to the value of 0.08 given in Table I. Variations can occur with the materials used in the wall.

ASSIGNMENT SHEET SB-7-1

CALCULATING R_T, U

Problem 1

A solid masonry wall consists of the following layers, having the resistances listed.

	R
Outside air film (15 mph wind, winter)	.17
Face brick (2-inch)	.22
Common brick (4-inch)	.80
Air space (4-inch, non-reflective)	1.01
Gypsum board (½-inch)	.45
Inside air film	.68

R_T =

What is the U value of the wall? Show the calculations below.

Problem 2

Calculate the R value for the following materials. (Remember that R = 1/k x (thickness of material).

a. stucco (4 inches thick)

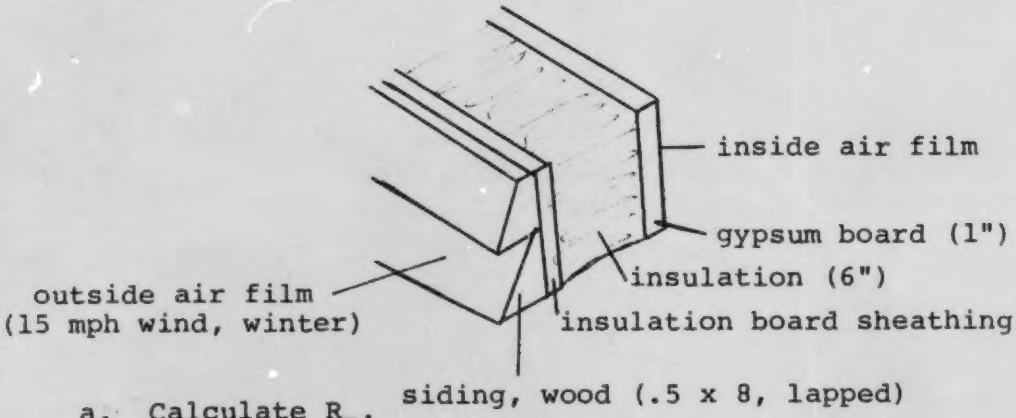
b. gypsum board (½-inch thick)

c. common brick (5-inches thick)

d. insulation (2-inches thick)

Problem 3

Consider the wall diagramed below.


inside air film
gypsum board (1")
insulation (6")
insulation board sheathing
outside air film
(15 mph wind, winter)
siding, wood (.5 x 8, lapped)

a. Calculate R_T.

b. Calculate U.

Problem 4

A floor consists of the following layers.

carpet and rubber pad
plywood (3/4-inch)
insulation (6-inch)
surface (still air-non-reflective-heat flow up)

What is the U value of the floor? Show the calculations below.

DEGREE DAYS AND DESIGN TEMPERATURES

In doing building heat load calculations, you will make frequent use of tables indicating degree days and design temperatures for specific geographical locations. Part of such a table is included at the back of this Information Sheet. It is important to understand not only how to use the data in such tables, but also, what the data means.

The two right-hand columns list the design temperatures for winter and summer. The winter design temperature is based on data gathered by the U.S. Weather Bureau over long periods of time. It describes a daily weather temperature which will be exceeded 99% of the time in a given geographical location. Consider the winter design temperature of Macon, Georgia, which is 23° F. This means that 99% of the time the winter daily temperature in Macon will exceed 23° F. Compare this to the winter design temperature in Sioux City, Iowa, which is -10° F. The difference in the winter design temperatures indicates that Sioux City is much colder than Macon in the winter. The lower the winter design temperature, the greater the rate of heat loss.

The summer design temperature is one which is exceeded only 1% of the time in the summer. Savannah, Georgia has a summer design temperature of 96° F. This means that the daily temperature in Savannah goes above 96° F only 1% of the time. Summer design temperatures are used in calculating cooling loads for air conditioning systems.

A degree day indicates the extent to which the daily temperature for a given area goes below some desirable indoor indoor temperature, usually 65° F. If the average temperature for January 7 in Athens, Georgia is 30° F, then the degree days for that day is 35 (65 - 30 = 35). The degree days for a given month are calculated by summing the degree days for each day of that month. The colder the month, the greater the number of degree days. For the month of January, Thomasville, Georgia has 394 degree days, while Athens, Georgia has 642 degree days, indicating that Athens is colder than Thomasville in January. For the month of July, Athens has 0 degree days, indicating that the daily temperature rarely goes below 65° F during that month.

The annual degree days are calculated by summing the degree days for each month of the year. The colder the average daily temperature, the greater the number of annual degree days.

NORMAL TOTAL HEATING DEGREE DAYS (Base 65^{o})													Design T_{o} ^{o}F	
STATE AND STATION	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	ANNUAL	WIN.	SUMM.
CALIF: Eureka	270	257	258	329	414	499	546	470	505	438	372	285	4643	32	67
Fresno	0	0	0	78	339	558	586	406	319	150	56	0	2492	28	101
Long Beach	0	0	12	40	156	288	375	297	267	168	90	18	1711	36	87
Los Angeles	28	22	42	78	180	291	372	302	288	219	158	81	2061	42	94
Mt. Shasta	25	34	123	406	696	902	983	784	738	525	347	159	5722		
Oakland	53	50	45	127	309	481	527	400	353	255	180	90	2870	35	85
Point Arguello	202	186	162	205	291	400	474	392	403	339	298	243	3595		
Red Bluff	0	0	0	53	318	555	605	428	341	168	47	0	2515		
Sacramento	0	0	12	81	363	577	614	442	360	216	102	6	2773	30	100
Sandberg	0	0	30	202	480	691	778	661	620	426	264	57	4209		
San Diego	6	0	15	37	123	251	313	249	202	123	84	36	1439	42	86
San Francisco	81	78	60	143	306	462	508	395	363	279	214	126	3015	42	80
Santa Catalina	16	0	9	50	165	279	353	308	326	249	192	105	2052		
Santa Maria	99	93	96	146	270	391	459	370	363	282	233	165	2967	32	85
COLO: Alamosa	65	99	279	639	1065	1420	1476	1162	1020	696	440	168	852[illegible]	-17	84
Colorado Springs	9	25	132	456	825	1032	1128	938	893	582	319	84	6423	- 1	90
Denver	6	9	117	428	819	1035	1132	938	887	558	288	66	6283	- 2	92
Grand Junction	0	0	30	313	786	1113	1209	907	729	387	146	21	5641	8	96
Pueblo	0	0	54	326	750	986	1085	871	772	429	174	15	5462	- 5	96
CONN: Bridgeport	0	0	66	307	615	986	1079	966	853	510	208	27	5617	4	90
Hartford	0	6	99	372	711	1119	1209	1061	899	495	177	24	6172	1	90
New Haven	0	12	87	347	648	1011	1097	991	871	543	245	45	5897	5	88
DEL: Wilmington	0	0	51	270	588	927	980	874	735	387	112	6	4930	12	93
FLA: Apalachicola	0	0	0	16	153	319	347	260	180	33	0	0	1308		
Daytona Beach	0	0	0	0	75	211	248	190	140	15	0	0	879	32	94
Fort Myers	0	0	0	0	24	109	146	101	62	0	0	0	442	38	94
Jacksonville	0	0	0	12	144	310	332	246	174	21	0	0	1239	29	96
Key West	0	0	0	0	0	28	40	31	9	0	0	0	108	55	90
Lakeland	0	0	0	0	57	164	195	146	99	0	0	0	661	35	95
Miami Beach	0	0	0	0	0	40	56	36	9	0	0	0	141	45	91
Orlando	0	0	0	0	72	198	220	165	105	6	0	0	766	33	96
Pensacola	0	0	0	19	195	353	400	277	183	36	0	0	1463	29	92
Tallahassee	0	0	0	28	198	360	375	286	202	36	0	0	1485	25	96

NORMAL TOTAL HEATING DEGREE DAYS (Base 65^o)														Design T_o ^{o}F	
STATE AND STATION	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	ANNUAL	WIN.	SUMM.
FLA: Tampa	0	0	0	0	60	171	202	148	102	0	0	0	683	36	92
West Palm Beach	0	0	0	0	6	65	87	64	31	0	0	0	253	40	92
GA: Athens	0	0	12	115	405	632	642	529	431	141	22	0	2929	17	96
Atlanta	0	0	18	127	414	626	639	529	437	168	25	0	2983	18	95
Augusta	0	0	0	78	333	552	549	445	350	90	0	0	2397	20	98
Columbus	0	0	0	87	333	543	552	434	338	96	0	0	2383	23	98
Macon	0	0	0	71	297	502	505	403	295	63	0	0	2136	23	98
Rome	0	0	24	161	474	701	710	577	468	177	34	0	3326	16	97
Savannah	0	0	0	47	246	437	437	353	254	45	0	0	1819	24	96
Thomasville	0	0	0	25	198	366	394	305	208	33	0	0	1529		
IDAHO: Boise	0	0	132	415	792	1017	1113	854	722	438	245	81	5809	4	96
Idaho Falls 46W	16	34	270	623	1056	1370	1538	1249	1085	651	391	192	8475		
Idaho Falls 42NW	16	40	282	648	1107	1432	1600	1291	1107	657	388	192	8760		
Lewiston	0	0	123	403	756	933	1063	815	694	426	239	90	5542	6	98
Pocatello	0	0	172	493	900	1166	1324	1058	905	555	319	141	7033	- 8	94
ILL: Cairo	0	0	36	164	513	791	856	680	539	195	47	0	3821		
Chicago	0	0	81	326	753	1113	1209	1044	890	480	211	48	6155	- 3	94
Moline	0	9	99	335	774	1181	1314	1100	918	450	189	39	6408	- 7	94
Peoria	0	6	87	326	759	1113	1218	1025	849	426	183	33	6025	- 2	94
Rockford	6	9	114	400	837	1221	1333	1137	961	516	236	60	6830	- 7	92
Springfield	0	0	72	291	696	1023	1135	935	769	354	136	18	5429	- 1	95
IND: Evansville	0	0	66	220	606	896	955	767	620	237	68	0	4435	6	96
Fort Wayne	0	9	105	378	783	1135	1178	1028	890	471	189	39	6205	0	93
Indianapolis	0	0	90	316	723	1051	1113	949	809	432	177	39	5699	0	93
South Bend	0	6	111	372	777	1125	1221	1070	933	525	239	60	6439	- 2	92
IOWA: Burlington	0	0	93	322	768	1135	1259	1042	859	426	177	33	6114	- 4	95
Des Moines	0	9	99	363	837	1231	1398	1163	967	489	211	39	6808	- 7	95
Dubuque	12	31	156	450	906	1287	1420	1204	1026	546	260	78	7376	-11	92
Sioux City	0	9	108	369	867	1240	1435	1198	989	483	214	39	6951	-10	96
Waterloo	12	19	138	428	909	1296	1460	1221	1023	531	229	54	7320	-12	91

ASSIGNMENT SHEET SB-7-2

USING DESIGN & DEGREE DAY DATA

a. Indicate the winter design temperature for:

Los Angeles, California ________
Dubuque, Iowa ________
Jacksonville, Florida ________

b. Indicate the annual degree days and degree days in January for each of the following locations:

	January	Annual
Rome, Georgia		
Chicago, Illinois		
New Haven, Connecticut		

c. For each of the pairs of locations listed below, circle the location which is colder in December.

Columbus, Georgia or Orlando, Florida
San Francisco, California or Sacramento, California
San Diego, California or Tampa, Florida

d. Indicated below are the average daily temperatures on January 20 for three different locations. Calculate the number of degree days for each location.

	Average Temperature on January 20	Degree Days
Buffalo, New York	20° F	
Atlanta, Georgia	32° F	
Miami, Florida	47° F	

HEAT LOSS RATE

The rate of heat loss, h, in Btu/hr through a surface of area, A, with a temperature difference across the two sides of the surface of T, is:

$$h = UA\Delta T,$$

where A is in square feet and ΔT is in degrees Fahrenheit.

The temperature difference that is used to calculate the heat loss rate is the difference between the room temperature, T_R, and the design outdoor temperature, T_O:

$$\Delta T = T_R - T_O$$

The room temperature is nominally 70 degrees and the design outdoor temperatures are tabled for many cities in the United States. Also listed in such tables are monthly and total annual heating degree days, which will be utilized in the heating load calculations. Table I in Information Sheet SB-7-2 is part of such a table.

CONCRETE SLABS ON GRADE

The heat loss rate from concrete slab on grade is calculated on the basis of exposed edge length rather than on floor area. The heat loss rate is:

$$h = U \text{ (linear feet of exposed slab area)} \Delta T$$

where ΔT is the difference between indoor and average outdoor temperature in degrees Fahrenheit. The U values are listed in Table I. (Information Sheet SB-7-1).

BASEMENTS

Basement floors below grade have a heat loss rate of about

$\frac{\text{1 Btu/hr}}{\text{ft}^2 \text{ of floor area}}$. In Table I,(Information Sheet SB-7-1), for

basement walls below grade, $U=0.06$ Btu/(hr)(ft^2)($^\circ$F). The temperature difference is the indoor temperature minus the ground temperature, and the ground temperature is often assumed to be the same as ground water temperature and, in most regions, can be assumed to be about 45° F in winter.

DUCT HEAT LOSS

When a duct is installed within the insulated envelope, there is no heat loss from the building. If the ducts are located in crawlspaces or outside the building envelope, about 10 percent of the heat carried by the duct will be lost.

INFILTRATION HEAT LOSS

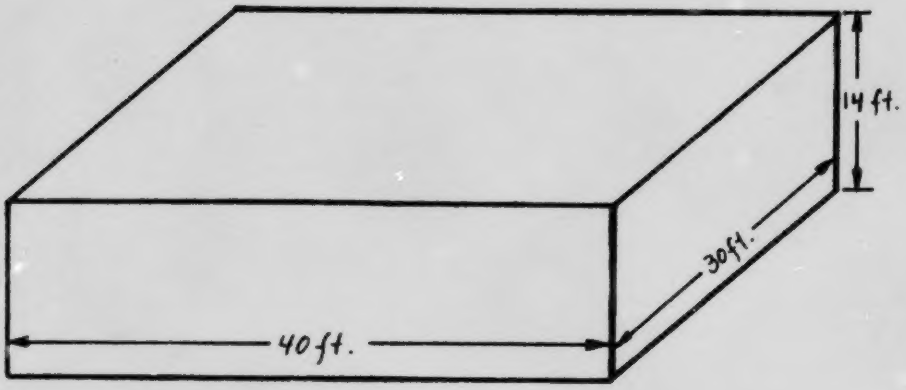
The cold air that enters a building through open doors, windows and cracks around doors and windows constitutes a heat loss because the cold air displaces the warm room air and the cold air must be heated to room air temperature. The infiltration heat loss rate can be computed from:

$$h = 0.018V(\Delta T)$$

where V is the volume flow rate, cubic feet of cold air per hour and ΔT is the difference in indoor and outdoor air temperatures. The volume flow is the air change rate per hour. For normal residential buildings, the air change rate averages about once per hour for all rooms located above grade.

CALCULATING RATE OF HEAT LOSS

The problems below involve calculating the rate of heat loss from different components of a representative building in Atlanta, Georgia. As illustrated below, the building is 30 feet x 40 feet x 14 feet, and has a flat ceiling.



Remember that a general rule for calculating the heat loss through any surface, be it wall, window, or ceiling, is:

$$\underset{\text{(Btu/hour)}}{\text{Rate of Heat Loss}} = UA\,(T_R - T_O)$$

where U = coefficient of heat transmission
A = surface area
T_R = indoor room temperature
T_O = outdoor design temperature

Problem 1

The walls are constructed as in Problem 1 of Assignment Sheet SB-6-1. What is the rate of winter heat loss through the outside walls, assuming no windows?

Problem 2

The house is built on a concrete slab on grade with 1" x 12" insulation. What is the rate of winter heat loss from the slab?

Problem 3

What is the rate of heat loss due to infiltration in the winter?

Problem 4

The ceiling of the house has a U value of .04. What is the rate of heat loss through the ceiling? (Note: Even though an attic may cover the ceiling, it is commonly assumed that the temperature of well-ventilated attic is about the same as the outdoor design temperature.)

Problem 5

What is the total rate of heating loss from the sources considered so far?

Problem 6

What other sources of heat loss must be considered in calculating the total rate of heat loss for an ordinary house?

SPACE HEAT LOSS AND HEAT LOAD CALCULATIONS

Heat loss calculations describe the number of Btu's lost per hour for a given source of heat loss. In calculating the total rate of heat loss per hour for a house, we first identify the sources of heat loss and then calculate the rate of heat loss from each source of heat loss (e.g., from exterior walls, basement walls, ceiling, infiltration). The rates of heat loss from each source are summed to determine the total rate of heat loss per hour for the house. Consider the example below.

Source of Heat Loss	Rate of Heat Loss
Exterior walls	7478 Btu/hr
Floor	3626 Btu/hr
Ceiling	6333 Btu/hr
Doors	2603 Btu/hr
Windows	10945 Btu/hr
Infiltration	18790 Btu/hr
Basement walls	1613 Btu/hr

Total rate of heat loss = 51,388 Btu/hr

For the purpose of sizing residential solar system components, we are interested not in the house's rate of heat loss per hour, but rather in the heating load during certain critical months, or over the entire year. To calculate these heating loads, we first calculate the space heating load per degree day (DD).

$$\text{Space Heating Load Btu/DD} = \frac{\text{House heat loss rate}}{\text{Design temperature difference}} \times 24 \text{ hr/day}$$

where house heat loss rate is the total Btu/hr lost from all sources.

Design temperature difference is the difference between room temperature (usually 65 or 70° F) and the area's design temperature for the season of interest (for space heating systems, ususally winter).

For example, if the total rate of heat loss for a house in Atlanta in the winter is 51,388 Btu/hr, the space heating load per degree day can be calculated as follows:

$$\text{Space Heating Load (Btu/DD)} = \frac{\text{House heat loss rate}}{\text{Design temperature difference}} \times 24 \text{ hr/day}$$

$$= \frac{51{,}388 \text{ Btu/hr}}{65^{\circ}\text{F}-18^{\circ}\text{F}} \times 24 \text{ hr/day}$$

$$= 26{,}240 \text{ Btu/DD}$$

To calculate the space heating load for a particular month, multiply the space heat load per degree day by the number of degree days in that month.

$$\text{Monthly heating load (Btu/Month)} = \text{Heat load per degree day} \times \text{number of degree days}$$

For example, the monthly heating load for the house in Atlanta in January is calculated as follows:

$$\text{Monthly heating load} = 26{,}240 \text{ Btu/DD} \times 639 \text{ degree days}$$

$$= 16{,}767{,}794 \text{ Btu}$$

The monthly heating load during the coldest winter month is frequently used to size the collector array for a solar space heating system. To simplify discussion of large heating loads, the monthly heating load may be expressed in millions of Btu's (mBtu). In the example above, 16,767,794 Btu can be more simply expressed as 16.8mBtu.

To determine the annual heat load, multiply the heat load per degree day by the annual number of degree days. The annual heating load for the house in Atlanta may be calculated as follows:

$$\text{Annual heat load} = \text{Heat load per degree day} \times \text{Annual number of degree days}$$

$$= 26{,}240 \text{ Btu/DD} \times 2983 \text{ DD}$$

$$= 78{,}273{,}920 \text{ Btu or } 78.3\text{mBtu}$$

CALCULATING SPACE HEATING LOAD

a. A house in Atlanta, Georgia has a heat loss of 40,140 Btu/hr. Calculate the following:

Space heating load, Btu/DD:

Monthly heating load, Btu (in February):

Annual heating load:

CALCULATING DOMESTIC HOT WATER HEATING LOAD

The daily heat load required for domestic hot water heating can be calculated using the following formula.

$$\begin{array}{c}\text{Hot water heating load}\\ \text{Btu/day}\end{array} = \begin{array}{c}\text{Number of}\\ \text{house occupants}\end{array} \times 16{,}680 \ \frac{\text{Btu}}{\text{(person)(day)}}$$

If a house has two occupants the daily hot water heating load is:

Daily hot water load = 2 x 16,680 = 33,360 Btu/day

The monthly hot water load is calculated by multiplying the daily hot water load by the number of days in that month. For the household described above, located in Atlanta, the monthly hot water for January is:

Monthly hot water load = Daily load x Days in Month

= 33,360 x 31

= 1,034,160 Btu

The annual hot water heating load is calculated by multiplying the daily heat load by the number of days in the year, or 365. For the household describe above:

Annual heat load = Daily load x 365

= 33,360 x 365

= 12,176,400 Btu or 12.2 mBtu

The annual heat load can also be accurately estimated by multiplying the heat of a representative month by the number of months in a year, or 12.

Annual heat load = Monthly load x 12

= 1,034,160 Btu x 12

= 12,409,920 Btu or 12.4 mBtu

CALCULATING DOMESTIC HOT WATER (DHW) LOAD

A household has five occupants. Calculate the heat load for:

a. Daily DHW heating

b. Monthly DHW heating (May)

c. Annual DHW heating

SUMMARY OF BUILDING HEAT LOAD CALCULATIONS

You are now familiar with all of the steps necessary to perform building heat load calculations. Before doing sample problems, you should review the steps listed below, and make sure you understand the method and purpose for performing each step.

I. Calculating rate of heat loss (Btu/hr) from spaces to be heated

1. Identify sources of heat loss
2. Calculate rate of heat loss from each
    - a. For walls and building surfaces
        - (1) Calculate total resistance (R_T)
        - (2) Calculate U
        - (3) Apply formula:

$$h\left(\begin{matrix}\text{Rate of heat}\\ \text{loss}\end{matrix}\right) = UA(T_i - T_o)$$

    - b. From infiltration
        - (1) Calculate building volume
        - (2) Apply formula:

$$h = .018V(T_i - T_o)$$

3. Sum rates of heat loss to obtain design heat loss rate

II. Calculate heat loads for space heating

1. Calculate space heating load per degree day

$$\text{Btu/DD} = \frac{\text{Design heat loss rate}}{\text{Design temperature difference}} \times 24 \text{ hr/day}$$

2. Calculate monthly heating load

$$\begin{matrix}\text{Monthly heating}\\ \text{load}\end{matrix} = \begin{matrix}\text{Heat load per}\\ \text{degree day}\end{matrix} \times \text{Monthly degree days}$$

3. Calculate annual heating load

$$\text{Annual heating load} = \text{Heat load per degree day} \times \text{Annual number of degree days}$$

III. Calculate heat load for domestic hot water heating (when included with space heating system)

1. Calculate daily hot water heating load

$$\text{Daily heating load} = \text{Number of Occupants} \times 16{,}680 \ \frac{\text{Btu}}{(\text{person})(\text{day})}$$

2. Calculate monthly hot water heating load

$$\text{Monthly heating load} = \text{Daily heating load} \times \text{Number of days in month}$$

3. Calculate annual heating load

$$\text{Annual heating load} = \text{Monthly heating load} \times \text{Number of months in year}$$

EXAMPLE

Calculate the January heating load (L, Btu/month), and the annual heating load (H, million Btu) for the following home:

Location: Albuquerque, New Mexico

Indoor Design Temperature: 70° F

Ceiling Height: 8'-0"

House Construction:
- Exterior walls:
  - 4" common brick
  - ½" plywood
  - 2x4 studs
  - R-11 insulation
  - ½" plasterboard
- Floor construction over vented crawlspace:
  - 25/32" hardwood finish flooring
  - building paper
  - 1" plywood sub-floor
  - air space
  - R-11 insulation (applied to underside of joists)
- Windows: Storm windows
- Exterior: 1-½" solid core door
- Ceiling construction with vented attic space above:
  - ½" plasterboard
  - R-19 insulation

House is 51' x 27', and has one wood exterior door 3' x 6'-8", and one double glass wood fram sliding patio door with ¼" air space, 7' x 6'-8"

The windows are as follows:

Number	Size
4	6' x 4'
3	3' x 5'
2	2' x 5'
1	2' x 3'
1	5' x 8'

The ducts are not installed within the insulation envelope.

Solution

Compute the U values for the various building sections as follows:

Exterior Wall	Thickness inches	1/k	R
Outside surface air film (15 mph)			0.17
Common brick	4	0.20	0.80
Plywood	.5	1.24	0.62
R-11 insulation			11
Plasterboard	.5	0.90	0.45
Inside surface air film			0.68
Total (Σ)			13.72

$U = 1/\Sigma R = 1/13/72 = 0.07$ Btu/(hr)(ft^2)($^\circ$F)

Floor	Thickness inches	1/k	R
Inside surface air film			0.92
Hardwood finish flooring	25/32		0.68
Building paper			0.06
Plywood sub-floor	1	1.24	1.24
Air space			1.01
R-11 insulation			11
Outside surface air film			0.17
Total (Σ)			15.08

$U - 1/\Sigma R = 1/15.08 = 0.07$ Btu/(hr)(ft^2)($^\circ$F)

Ceiling	Thickness inches	1/k	R
Inside surface air film			0.61
Plaster board	.5	0.9	0.45
R-19 Insulation			19
Outer surface air film			0.17
Total (Σ)			20.23

$U = 1/\Sigma R = 1/20.23 = 0.05$ Btu/(hr)(ft^2)($^\circ$F)

The winter design outdoor temperature for Albuquerque, New Mexico, is 14° F. With the room temperature set at 70° F, $\Delta T = T_R - T_O = 70 - 14 - 56^\circ$ F. The values of U for this house are summarized below.

	U, Btu/(hr)(ft^2)(°F)
Exterior wall	0.07
Windows	0.56
Floor	0.07
Ceiling	0.05
Exterior door (1-½" solid core)	0.49
Double glass sliding patio door	0.65

The heat loss calculations and the domestic hot water load can be systematized by using worksheets TA-1. The heating loads for the house in this example are worked out on the worksheets shown on the following pages.

Worksheet TA-1
Sheet 1 of 2

Building Heat Load Calculations

Job Example
Number of Occupants 4
Computed by
Date Jan 13, 1977
Location Albuquerque N.M.
Latitude 35°N

Indoor temperature, T_R, 70 °F
Design winter outdoor temperature, T_O. 14 °F
Design temperature difference 56 °F
Design degree-day, 65 - T_O, 51 °F

Building Dimensions:
Above Grade: Length 51 ft Width 27 ft Ceiling Height 8 ft
Below Grade: Length 0 ft Width 0 ft Depth 0 ft
Concrete Floor Slab: Exposed perimeter 0 ft

Exterior Wall Area: 8 × (51 + 27) × 2 = 1248 ft^2

Window Area: 4 × (6 × 4) + 3 × (3 × 5) + 2 × (2 × 5)
+ 1 × (2 × 3) + 1 × (5 × 8) = 207 ft^2

Door Area: Wood Door 3 × 6'-8" = 20 ft^2
Patio Door 7 × 6'-8" = 47 ft^2

Net Exterior Wall Area: 1248 - 207 - 20 - 47 = 974 ft^2

Ceiling Area: 27 × 51 = 1377 ft^2

Floor Area: 27 × 51 = 1377 ft^2

Basement Wall Area: 0

Heating Degree-Days: January 930 °F-days
Annual 4348 °F-days

Worksheet TA-1
Sheet 2 of 2

		U Btu / $(hr)(ft^2)(^\circ F)$	A	ΔT °F $(T_R - T_o)$	$h = UA\Delta T$ Btu/hr
Exterior Walls (net)		0.07	974	56	3820
Basement Walls	Above grade				—
	Below grade			*	—
Windows and Sliding Patio Doors	Single				—
	Double	0.65	47	56	1710
	Triple				—
	Storm	0.56	207	56	6490
Exterior Slab Doors		0.49	20	56	550
Floors	Over Crawlspace	0.07	1377	56	5400
	Concrete Slab on Grade				—
	Basement				—
Ceiling		0.05	1377	56	3860
Subtotal (walls, windows, doors, floors, ceiling)					21,830
Infiltration: (0.018) x 27x51x8 ft³ x 56 °F					11,100
Duct = 10% of subtotal (if ducts not in insulation envelope)					2180
Design Heating Load: Btu/hr					35,110
Design Heating Load: Btu/DD Design Heating Load (Btu/hr) X (24 hr/Design TD)					15,050
January Heating Load: m Btu (Btu/DD) X (January DD)					14.0
Annual Heating Load: m Btu (Btu/DD) X (Annual DD)					65.4

* $\Delta T = T_R - 45^\circ$

DOMESTIC HOT WATER LOAD

Number of occupants X 16,680 Btu/day	66,720
January Load (m Btu) (Btu/day) x 31 x 10^{-6}	2.1
Annual Load (m Btu) (January load x 12)	24.8

ASSIGNMENT SHEET SB-7-6

PROBLEMS

PROBLEM

For the home plan shown in Figure 1, calculate the January and annual heating loads. Assume that an internal temperature of 68° F is to be maintained. The home is located in For Collins, Colorado, where the design winter outdoor air temperature is -9° F. The three-bedroom home will be occupied by four people. The first floor ceiling height is 97 inches, the entrance hall ceiling height is 111 inches, and the basement ceiling height is 92 inches. The entire basement is below grade and is heated. The entrance hall has a concrete slab floor with no perimeter insulation. All ducts are within the building envelope. Basement walls are 7.5-inch thick concrete.

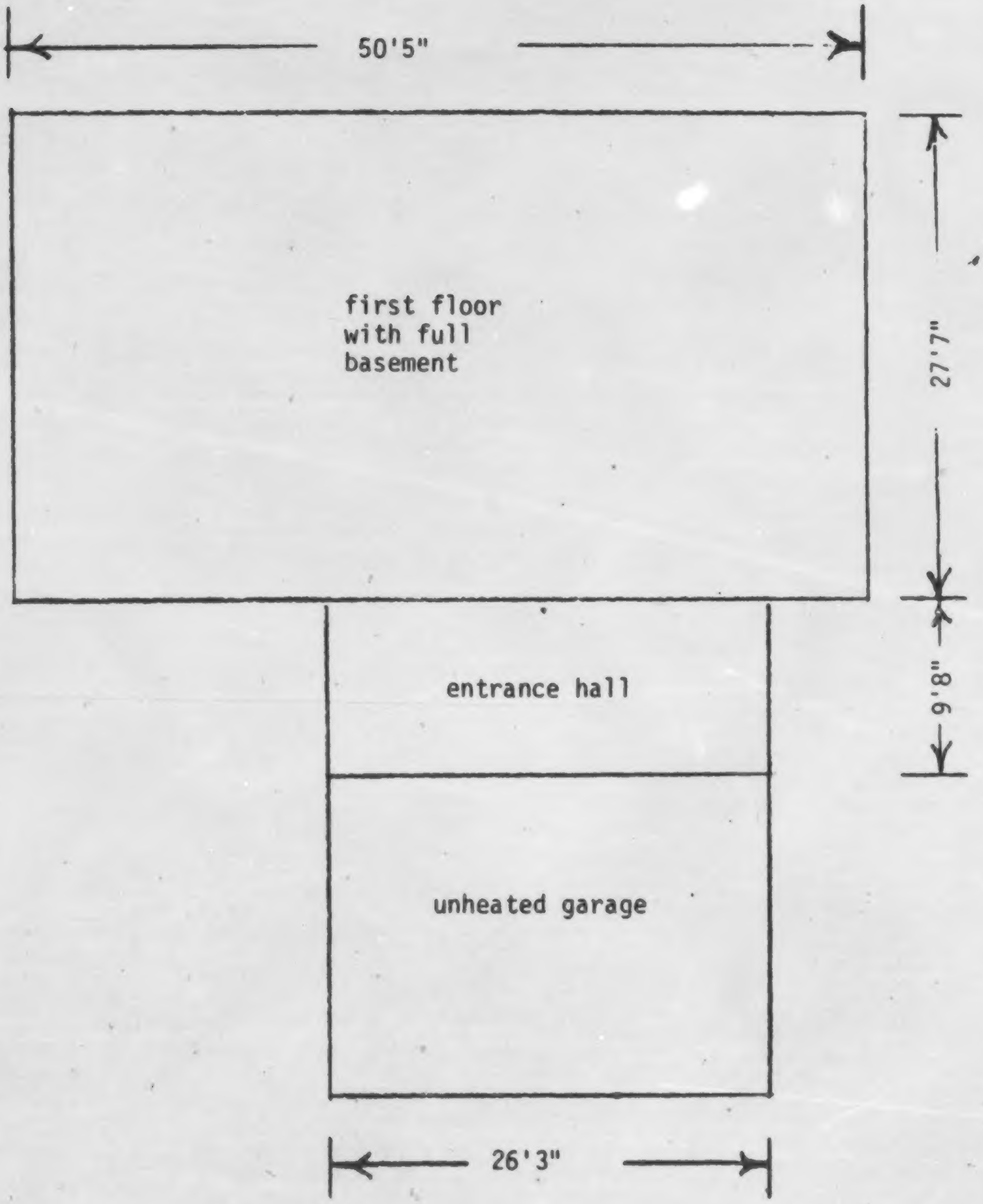
All exterior doors are in the hall. Their sizes are given in the following table:

Door	Thickness	Size
Front door	1.5"	81" x 65"
2 doors between entrance hall and garage (each)	1.5"	80" x 29"
2 sliding patio doors (metal frame) one single glass and one double glass (.25" air space) each		80" x 35.5"

The house contains the following windows, which are all storm windows except as specified:

Window	Size
Entrance hall (single glass)	16" x 57"
Kitchen window	32" x 35"
2 dining room windows, each	32" x 43"
2 living room (.25" air space) double glazed (not storm windows), each	13" x 61"
2 living room picture windows, each	47" x 53"
4 bedroom windows, each	32" x 43"
6 basement windows, each	21" x 32"

The ceiling consists of ½-inch plasterboard and insulating batts 5-¼" thick. The exterior wall consists of ½" plasterboard, 3-½" batt insulation, and ¼" hardboard siding. The January heating degree-days for Fort Collins is 1,250 (°F)(days) and the annual degree-days is 6,300 (°F)(days). This home is heated with natural gas.


50'5"
first floor
with full
basement
27'7"
entrance hall
9'8"
unheated garage
26'3"

Scale: 1" = 10'

Figure 1. Outline of the Building in Problem

Worksheet TA-1
Sheet 1 of 2

Building Heat Load Calculations

Job ______________________ Number of Occupants ______

Computed by ______________________ Date ______________

Location ______________________ Latitude ______________

Indoor temperature, T_R, ______________ °F

Design winter outdoor temperature, T_O. _____ °F

Design temperature difference ___________ °F

Design degree-day, 65 - T_O, ___________ °F

Building Dimensions:

Above Grade: Length _____ ft Width _____ ft Ceiling Height _____ ft

Below Grade: Length _____ ft Width _____ ft Depth ___________ ft

Concrete Floor Slab: Exposed perimeter _____ ft

Exterior Wall Area: ______________________

Window Area: ______________________

Door Area: ______________________

Net Exterior Wall Area: ______________________

Ceiling Area: ______________________

Floor Area: ______________________

Basement Wall Area: ______________________

Heating Degree-Days: January _________ °F-days
Annual _________ °F-days

234

Worksheet TA-1
Sheet 2 of 2

		U Btu $\frac{}{(hr)(ft^2)(^oF)}$	A	ΔT °F (T_R - T_o)	h = UA ΔT Btu/hr
Exterior Walls (net)					
Basement Walls	Above grade				
	Below grade			*	
Windows and Sliding Patio Doors	Single				
	Double				
	Triple				
	Storm				
Exterior Slab Doors					
Floors	Over Crawlspace				
	Concrete Slab on Grade				
	Basement				
Ceiling					
Subtotal (walls, windows, doors, floors, ceiling)					
Infiltration: (0.018) x ________ ft³ x ________ °F					
Duct = 10% of subtotal (if ducts not in insulation envelope)					
Design Heating Load: Btu/hr					
Design Heating Load: Btu/DD Design Heating Load (Btu/hr) X (24 hr/Design TD)					
January Heating Load: m Btu (Btu/DD) X (January DD)					
Annual Heating Load: m Btu (Btu/DD) X (Annual DD)					

* $\Delta T = T_R - 45°$

DOMESTIC HOT WATER LOAD

Number of occupants X 16,680 Btu/day	
January Load (m Btu) (Btu/day) x 31 x 10^{-6}	
Annual Load (m Btu) (January load x 12)	

SOLAR HEATING SYSTEMS CURRICULUM
UNIT LISTING

PHASE A: BASIC UNDERSTANDING

Unit	Task
SA-1	Explain the value of solar energy and principles of solar radiation.
SA-2	Describe basic solar system components and their functions.

PHASE B: DESIGN

Unit	Task
SB-1	Recommend non-solar energy conservation measures.
SB-2	Select passive solar approaches for new construction.
SB-3	Recommend collectors.
SB-4	Recommend and site the thermal storage unit.
SB-5	Recommend control devices.
SB-6	Recognize and describe modes of solar system operation.
SB-7	Calculate heat load for space or domestic hot water heating.
SB-8	Size solar system components.
SB-9	Perform a solar system economic analysis.
SB-10	Recommend a domestic hot water system.

PHASE C: INSTALLATION

Unit	Task
SC-1	Recommend correct thermal mass for direct gain system; fabricate and install modular wall units for passive solar.
SC-2	Schedule solar installation.
SC-3	Install a liquid storage tank.
SC-4	Site and mount collectors.
SC-5	Install liquid collectors and outside plumbing.
SC-6	Install inside plumbing for collector load side loops.
SC-7	Install controls and wiring.
SC-8	Start up system.

PHASE D MAINTENANCE

Unit	Task
SD-1	Maintain the solar system.
SD-2	Troubleshoot solar system problems

MAJOR BLOCK Solar System (Phase B:Design) **NAME** ____________

TASK Size solar system components

UNIT SB-8 **TIME** (est.) ________ (act.) ______

OBJECTIVE(S) The student will be able to:
1) Use tables for collector sizing
2) list factors affecting the design of F-Charts, and use a supplied F-Chart
3) Size storage units by rule of thumb, or by considering heat load
4) List factors affecting heat exchanger sizing
5) Size an expansion tank
6) List conditions necessary to size a heat coil
7) Choose a heat coil given appropriate tabled information.

START	➡	W-1	L-1	W-2	L-2	W-3	W-4	W-5	L-3
C-1	W-6	W-7	L-4	W-8	L-5	C-2	C-3		

WRITTEN ASSIGNMENT(S)		**AUDIOVISUAL(S)**	
W-1	Assignment SB-8-1	A-1	
W-2	Assignment SB-8-3	A-2	
W-3	Information Sheet SB-8-1	A-3	
W-4	Information Sheet SB-8-2	A-4	
W-5	Assignment SB-8-5	A-5	
W-6	Information Sheet SB-8-3	A-6	
W-7	Assignment SB-8-7	A-7	
W-8	Assignment SB-8-9		

LABORATORY ASSIGNMENT(S)		**CHECKPOINT(S)**	
L-1	Assignment SB-8-2	C-1	Progress Check (written quiz)
L-2	Assignment SB-8-4	C-2	Progress Check (written quiz)
L-3	Assignment SB-8-6	C-3	Test (written)
L-4	Assignment SB-8-8	C-4	
L-5	Assignment SB-8-10	C-5	
L-6		C-6	
L-7		C-7	
L-8		C-8	
L-9		C-9	

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ACTIVITY SEQUENCE SHEET

Activity	Flow Chart Number	Description of Activity
Assignment SB-8-1	W-1	Read Fundamentals, page 6-1 to 6-3 (up to "F-Chart collector selection technique.") Note that MBTU is used to represent thousands of Btu's, not millions, in Table 6-1.
Assignment SB-8-2	L-1	Answer questions on Assignment Sheet SB-8-2.
Assignment SB-8-3	W-2	Read Fundamentals, page 6-3 to 6-6 (sections on "F-Chart collector selection technique" and "Economical collector sizing"
Assignment SB-8-4	L-2	Answer questions on Assignment Sheet SB-8-4.
Information Sheet SB-8-1	W-3	Read Information Sheet SB-8-1.
Information Sheet SB-8-2	W-4	Read Information Sheet SB-8-2.
Assignment SB-8-5	W-5	Read Fundamentals, page 6-8 (up to "Sizing the heat storage Unit") Note that there are errors in Figure 6-9. The calculation for increased collector area should be: $a = \frac{1}{.90} - 1 = 11\%$
Assignment SB-8-6	L-3	Answer questions on Assignment Sheet SB-8-6.
Progress Check	C-1	Written quiz.
Information Sheet SB-8-3	W-6	Read Information Sheet SB-8-3.
Assignment SB-8-7	W-7	Read Fundamentals, page 6-8 to 6-10 (sections on "Sizing the heat storage unit" and "Sizing heat exchangers"). Note the comparison of the rule of thumb and the more precise methods for calculating storage size.

Assignment SB-8-8	L-4	Answer the study questions on Assignment Sheet SB-8-8.
Assignment SB-8-9	W-8	Read Fundamentals, page 6-10 to 6-14 (from "Sizing air cushion tanks" to end of chapter).
Assignment SB-8-10	L-5	Answer the study questions on Assignment Sheet SB-8-10.
Progress check	C-2	Peer quiz.
Test	C-3	Unit test (written)

Answer the following study questions:

a. You are installing a solar system using Fedders collectors in Atlanta, Georgia. You want the collectors to supply 14.0 mBtu during January. How many collectors are required?

How many collectors are required to supply the same amount of heat in October?

Why is there a difference in the number of collectors required in July versus January?

b. Use the LC divisor method to solve the following problem. You are designing a collector array for a house in Griffin, Georgia. The heat loss is 53,000 Btu per hour with a 22° F average outdoor temperature and a 68° F average indoor temperature. What collector area is required to supply 50% of the total heat?

What area is required to supply 75% of total heat?

c. Use the SMACNA procedure to choose an appropriate collector array size for the case described in problem b, with a liquid solar array supplying 50% of the heat. The collector tilt angle is 53° F.

d. Why do the SMACNA procedure and the LC divisor method estimate different collector array sizes?

ASSIGNMENT SHEET SB-8-4

Answer the study questions below.

a. What are the two factors whose ratio is X?

b. What are the two factors whose ratio is Y?

c. What does f represent?

d. For liquid solar systems, what fraction of monthly energy is supplied for systems having the following X and Y values?

	Fraction of Monthly Energy Supplied
x = 9, y = 1.00	
x = 12, y = 2.75	
x = 2, y = .25	

e. Which of the above systems is probably most economical? Why ?

f. If you wanted to design a liquid system supplying 60% of the monthly energy, what would be one possible pair of X and Y values for your system?

DOING F-CHART CALCULATIONS

This Information Sheet explains in greater detail how X and Y can be calculated by hand for any solar system. All students should read pages 1 and 2. These pages familiarize you with the factors that contribute to the values of X and Y. You are not expected to be able to calculate X and Y, but you should be familiar with the factors influencing them. The remaining pages are optional worksheet pages which you may use if you wish to learn exactly how to calculate X and Y values.

USING THE F-CHART METHOD TO PREDICT THERMAL PERFORMANCE

General Procedure

Two-dimensionless parameters hereafter referred to as X and Y must be calculated for each month. Then f, the fraction of the monthly energy demand supplied by solar energy, can be obtained from graphs. Knowing f and the energy demand for each month, f_a the fraction of the annual energy demand supplied by solar energy can be calculated.

Several worksheets have been prepared to organize the required calculations. Worksheet TA-1 should be used to calculate the monthly total-energy demands on the solar-heating system. The remaining items which combine to form X and Y are conveniently organized on Worksheet TA-2. The fraction of the total heating load supplied by solar energy for several collector areas can be tabulated on Worksheet TA-3.

The parameter X represents the ratio of solar collector energy losses at a reference operating condition, to the total system heating demand. Y is the ratio of solar energy absorbed by the collector to the total system heating demand. These ratios are calculated for each month of the year. In equation form:

$$X = \frac{F_R' U_L A(T_{ref} - \bar{T}_a)\Delta\tau}{L} = F_R U_L \left[\frac{F_R'}{F_R}\right] \frac{A(T_{ref} - \bar{T}_a)\,\Delta\tau}{L}$$

$$Y = \frac{F_R' (\overline{\tau\alpha}) A H_T}{L} = F_R(\tau\alpha)_n \left[\frac{F_R'}{F_R}\right]\left[\frac{\bar{\tau}}{\tau_n}\right]\left[\frac{\bar{\alpha}}{\alpha_n}\right] \frac{AH_T}{L}$$

where

1) $F_R U_L$ and $F_R(\tau\alpha)_n$ are from flat plate collector manufacturer's specification sheets.

2) F_R'/F_R is the collector-tank heat exchanger performance penalty.

3) A is the collector area.

4) T_{ref} is 212°F.

5) $\bar{T}_a$ is the average ambient temperature for the month and location from Section II.

6) $\Delta\tau$ is the number of hours in the month.

7) L is the sum of the space heating and domestic hot water energy requirements over the month.

8) $\bar{\tau}/\tau_n$ is 0.95 for near optimum collector orientations.

9) $\bar{\alpha}/\alpha_n$ is 0.95 for near optimum collector orientations.

10) H_T is the solar radiation incident on the collector from Section II.

The following sections explain how to fill in Worksheets TA-1, TA-2 and TA-3. The text tells how to calculate or obtain each of the items which make up X and Y.

Worksheet TA-1

The monthly energy demand (L) is the sum of space heating and domestic water heating requirements. The space heating load (SHL) can be estimated as follows:

$$\text{SHL} = (24)(\text{UA})(\text{degree days})\ [\text{Btu}]$$

where

$$\text{UA} = \frac{\text{Design heat loss rate}}{\text{Design temp. difference}} \quad \left[\frac{\text{Btu}}{\text{hr}\,^\circ\text{F}}\right]$$

Degree days from Section II (or ASHRAE guide)

The design heat loss rate is calculated in the conventional manner with indoor and outdoor design temperatures as recommended by ASHRAE or required by code.

The domestic water heating load (DWL) is estimated as follows:

$$\text{DWL} = (\text{demand})(\text{specific heat of water})(T_{\text{supply}} - T_{\text{main}})$$

Assuming water is supplied to the taps at 140°F and main or well water enters the system at 55°F, this equation simplifies to:

$$\text{DWL} = (\text{gal/day})\ (706\ \text{Btu/gal})\ (\text{days/month})\ [\text{Btu}]$$

then

$$L = \text{SHL} + \text{DWL}\ [\text{Btu}].$$

WORKSHEET TA-1
HEATING LOADS

$$UA = \frac{\text{Design SHL=}\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_}{\text{Design }\Delta T\text{=}} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \text{ [Btu/hr - °F]}$$

Water Usage = ____________ [gal/day]

Month	Heating Degree Days [°F-day]	SHL [Btu] (1)	DWL [Btu] (2)	L [Btu] (3)
Jan				
Feb				
Mar				
Apr				
May				
Jun				
Jul				
Aug				
Sep				
Oct				
Nov				
Dec				
Total				

(1) SHL = (24)(UA)(Degree-Days from Section III)

(2) DWL = (gal/day usage)(706 Btu/gal)(days per month)

(3) L = SHL + DWL

Worksheet TA-2

Lines A and B -- F_RU_L and $F_R(\tau\alpha)_n$ are parameters which characterize the performance of flat-plate collectors. They are obtained from plots of collector efficiency (η) versus collector inlet temperature minus ambient temperature divided by incident solar radiation (i.e. $(T_{in} - T_a)/H_T$). The plots are straight-line fits of experimental data and should be supplied by the collector manufacturer. The experimental data must be taken for the collector flow rate with which your system will operate. As seen in the sample plot in Figure 6-3, $F_r(\tau\alpha)_n$ is the η-axis intercept and F_RU_L is the slope.

For an air-type collector, the efficiency data is often presented in a different format than water type collectors. If an air system is being simulated, a correction to the collector efficiency slope and intercept must be made. A detailed explanation of this correction is presented on pages 6-57 through 6-58.

F_R'/F_R is a factor which accounts for the performance penalty due to the heat exchanger between the collector and water storage tank in liquid-based systems like the one in Figure 6-1. The value of F_R'/F_R can be obtained from Figure 6-4 if $(\dot{m}C_p)_c/(F_RU_LA)$ and $\epsilon_c(\dot{m}C_p)_{min}/(\dot{m}C_p)_c$ are known.

$(\dot{m}C_p)_c$ is the mass flow rate times the specific heat of the fluid flowing through the collector. $(\dot{m}C_p)_{min}$ is the mass flow rate times the specific heat of either the collector fluid or the tank side heat exchanger fluid, depending on which is smallest. A is the collector area and ϵ_c is the effectiveness of the heat exchanger. Knowing the fluids and flow rates to be used on both sides of the heat exchanger and the size of the heat exchanger, ϵ_c can be calculated from relations given in Chapter 2 of the 1972 ASHRAE Handbook of Fundamentals. A typical value of ϵ_c is approximately 0.7. Exact values can be obtained from manufacturers heat exchanger data.

When designing a system it is easiest to choose an allowable heat exchanger penalty (e.g., $F_R'/F_R = 0.9$); use Figure 6-4 to determine ϵ_c and go to manufacturer's specification data to select the heat exchanger. Several values of F_R'/F_R can be tried, and using f-chart and the companion economic analysis, an economic heat exchanger size can be determined.

WORKSHEET TA-2

ITEMS MAKING UP X AND Y

A. $F_R U_L (F_R'/F_R)$ = ________________.

B. $F_R (\tau\alpha)_n (F_R'/F_R)$ = ________________.

	C1	C2	C3	C4	C5	C6	C7	C8
	L (1)	$(T_{ref} - \bar{T}_a)$ (2)	$\Delta\tau$	$\frac{(C2)(C3)}{(C1)}$	$\bar{\tau}/\tau_n$ (3)	$\bar{\alpha}/\alpha_n$ (4)	H_T (5)	$\frac{(C5)(C6)(C7)}{(C1)} (\frac{days}{mo.})$
Jan			744					
Feb			672					
Mar			744					
Apr			720					
May			744					
Jun			720					
Jul			744					
Aug			744					
Sep			720					
Oct			744					
Nov			720					
Dec			744					

(1) L from Worksheet TA-1

(2) T_{ref} is 212°F, $\bar{T}_a$ from Section III

(3) $\bar{\tau}/\tau_n$ is .95 for near optimum collector orientations

(4) $\bar{\alpha}/\alpha_n$ is .95 for near optimum collector orientations

(5) from Section II

(6) Column C8 is the number (C5) x (C6) x (C7) x (days per month)/(C1)

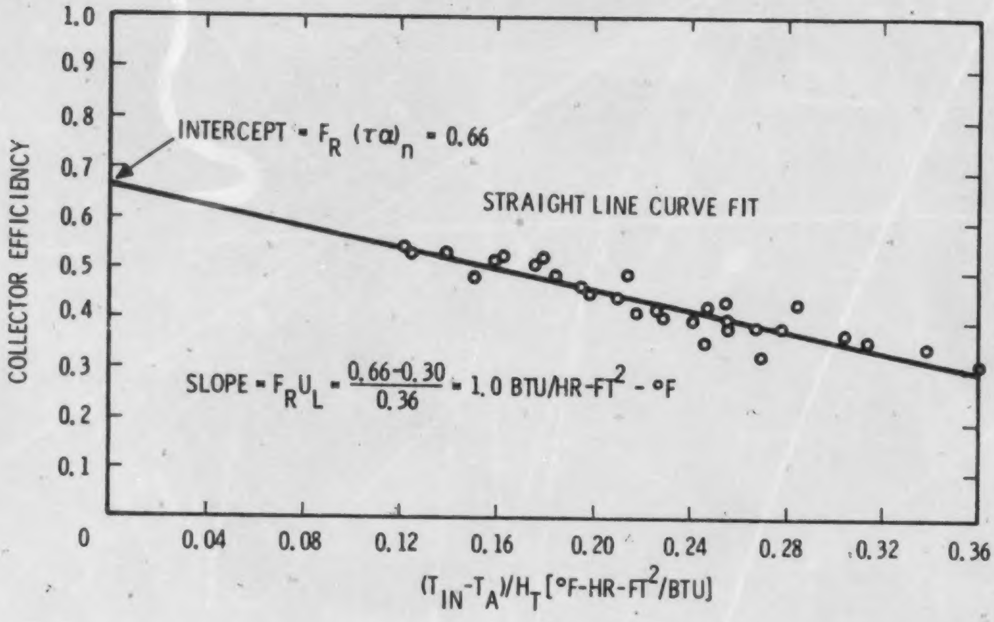

Figure 6-3. Experimental Collector Performance

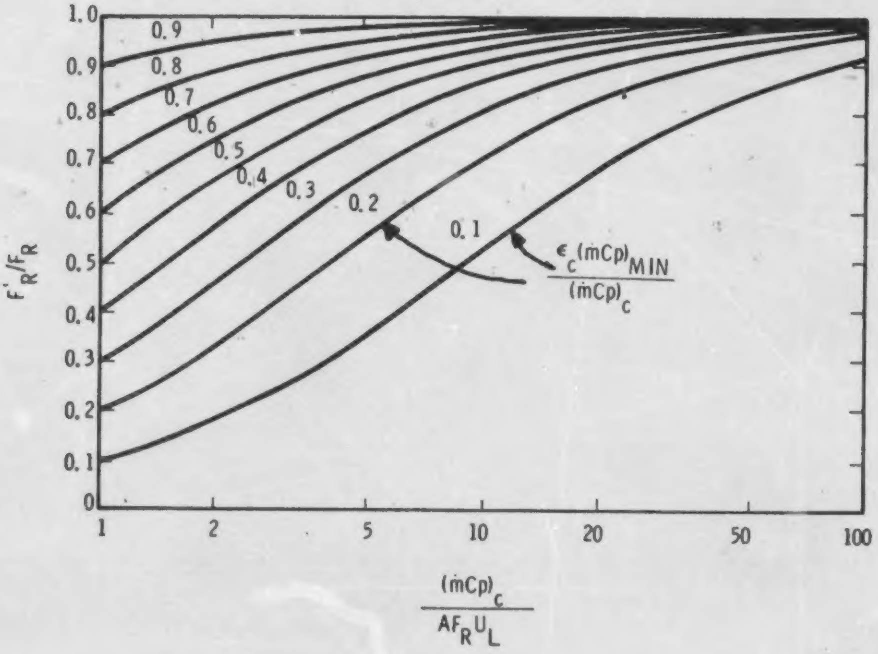

Figure 6-4. Collector Heat Exchanger Correction Factor

$F_R'/F_R = 1$ for air systems or liquid based systems that drain the collectors at night, since no heat exchanger is used between the collector and storage unit.

Column 1 -- Transcribe the monthly energy demands, L, from Worksheet TA-1.

Column 2 -- T_{ref} is 212°F. $\bar{T}_a$ is obtained from Section II.

Column 5 -- $\bar{\tau}/\tau_n$ is the ratio of the monthly average collector cover transmittance to the transmittance at normal incidence. For collectors facing due south and tilted at angles between the latitude and the latitude plus 20°, $\bar{\tau}/\tau_n = 0.95$ is a good approximation. For more extreme orientations $\bar{\tau}/\tau_n = 0.90$ is usually conservative although there are cases where the ratio is lower.

Column 6 -- $\bar{\alpha}/\alpha_n$ is the ratio of the collector surface solar absorptance to the solar absorptance at normal incidence. Experimental data quantifying the effect of angle of incidence on the collector plate solar absorptance is presently not available. Although it is not expected that selective and non-selective coatings are affected in the same way, for most collector orientations $\bar{\alpha}/\alpha_n = 0.95$ can be used as a conservative approximation for both coatings.

Column 7 -- Long term average values of solar radiation incident on collector surfaces of various orientations are tabulated in Section II.

Column 8 -- Product of (C5) by (C6) by (C7) by the number of days in each month divided by (C1).

Worksheet TA-3

Worksheet TA-3 is used to summarize the f-chart performance predictions. Room is available for three different collector areas. The dimensionless parameters X and Y, which describe the system, are calculated as:

X = (Column 4, Worksheet TA-2)(Line A, Worksheet TA-2)
(Collector area)

WORKSHEET TA-3

				Corrected	Corrected	Area = ____		Area = ____		Area = ____	
	L (1)	X (2)	Y (3)	X (4)	Y (5)	f (6)	fxL (7)	f (6)	fxL (7)	f (6)	fxL (7)
Jan											
Feb											
Mar											
Apr											
May											
Jun											
Jul											
Aug											
Sep											
Oct											
Nov											
Dec											
total						total		total		total	

Annual Fraction by Solar = (total, column 7)/(total, column 1) = ________ = ________ = ________

(1) L from Worksheet TA-1

(2) X = (TA-2, Column 4)(TA-2, line A)(Collector Area)

(3) Y = (TA-2, Column 8)(TA-2, line B) (Collector Area)

(4),(5) Corrected X and Y accounting for storage size, load heat exchanger size or collector flow rate

(6) f from Figure 8 or 9

Y = (Column 8, Worksheet TA-2)(Line B, Worksheet TA-2)
(Collector area)

for each month.

If the system being analyzed is liquid-based as in Figure 6-1, X and Y have been calculated assuming a certain size storage unit and load heat exchanger. The default storage size is two gallons of water per square foot of collector. For different sized storage units, X for each month must be adjusted as follows:

$$X = X_o \left(\frac{X}{X_o}\right)$$

where

X_o = the old value of X

$\left(\frac{X}{X_o}\right)$ from Figure 6-5.

The default heat exchanger is sized so that $\epsilon_L(\dot{m}C_p)_{min}/UA = 2$ where ϵ_L is the effectiveness of the load heat exchanger. $(\dot{m}C_p)_{min}$ is the mass flow rate times specific heat of either the storage tank side fluid or the load side fluid, whichever is smaller. UA has been calculated on Worksheet TA-1. For different sized heat exchangers, Y for each month must be modified as follows:

$$Y = Y_o \left(\frac{Y}{Y_o}\right)$$

where

Y_o = the old value of Y

$\left(\frac{Y}{Y_o}\right)$ from Figure 6-6.

ϵ_L can be calculated with the relations given in Chapter 2 of the 1972 ASHRAE Handbook of Fundamentals.

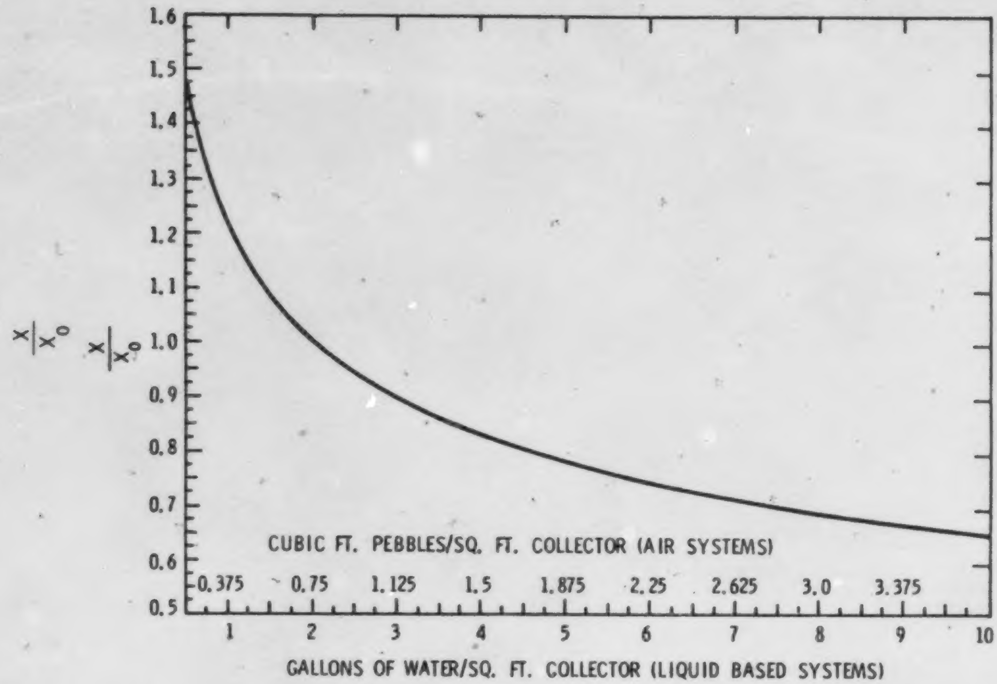

Figure 6-5. Storage Size Correction Factor

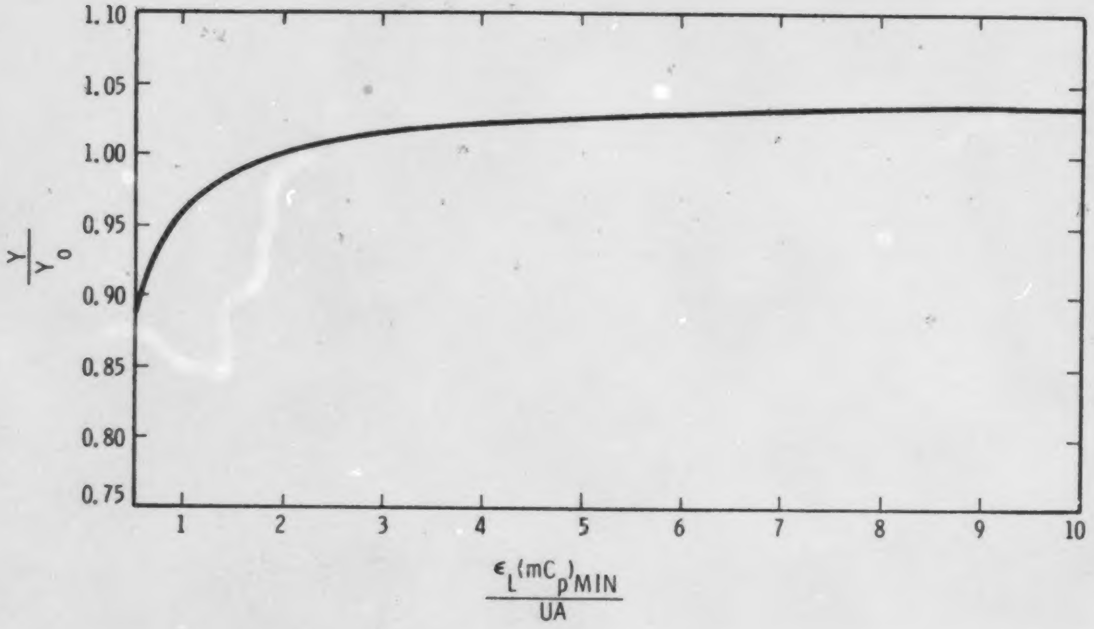

Figure 6-6. Load Heat Exchanger Correction Factor

If the system being analyzed is an air heating system as in Figure 6-2, X and Y have been calculated assuming a certain size storage unit and collector flow rate. The default storage size is 0.75 cubic feet of pebbles per square foot of collector. For different storage sizes correct X each month as

$$X = X_o \left(\frac{X}{X_o} \right)$$

where

X_o = the old value of X

$\left(\frac{X}{X_o} \right)$ from Figure 6-5.

The default value of collector flow rate is 2 SCFM per square foot of collector. For other flow rates, correct X as follows:

$$X = X_o \left(\frac{X}{X_o} \right)$$

where

X_o = the old value of X

$\left(\frac{X}{X_o} \right)$ from Figure 6-7.

Space is available on Worksheet TA-3 for both X and Y and the corrected values of X and Y. Using the corrected values in Figure 6-8, for liquid systems, and Figure 6-9, for air systems, yields f, the fraction of the load supplied by solar energy for the month.

The monthly loads can be transcribed from Worksheet TA-1. Then the energy supplied by the solar system each month can be calculated as f x L. The ratio of the annual energy supplied by solar to the annual load can then be expressed as

$$\mathfrak{F}_g \text{ annual load fraction by solar} = \frac{\sum_{i=1}^{12} f_i \times L_i}{\sum_{i=1}^{12} L_i}$$

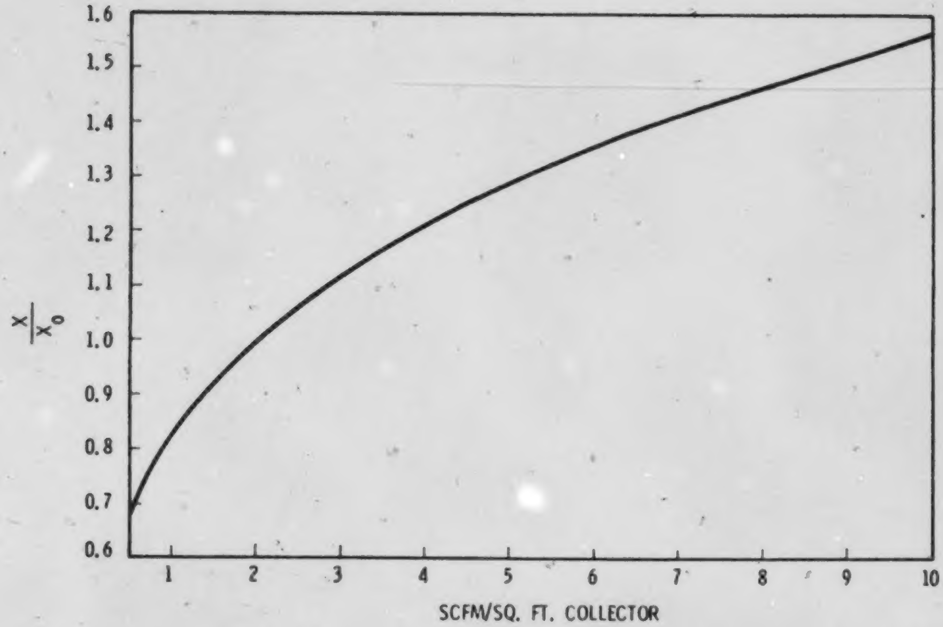

Figure 6-7. Collector Air Flow Rate Correction Factor

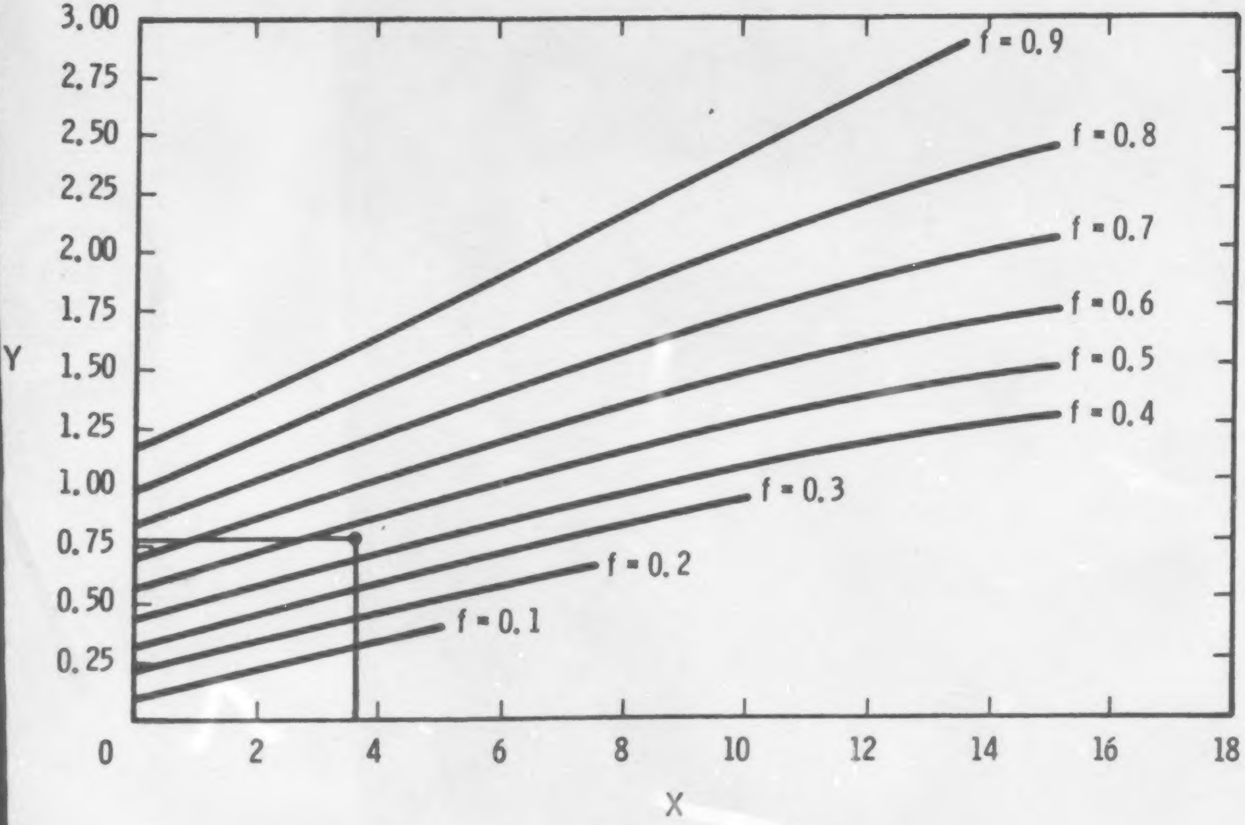

Figure 6-8. f - Chart for Liquid-Based Solar Heating Systems

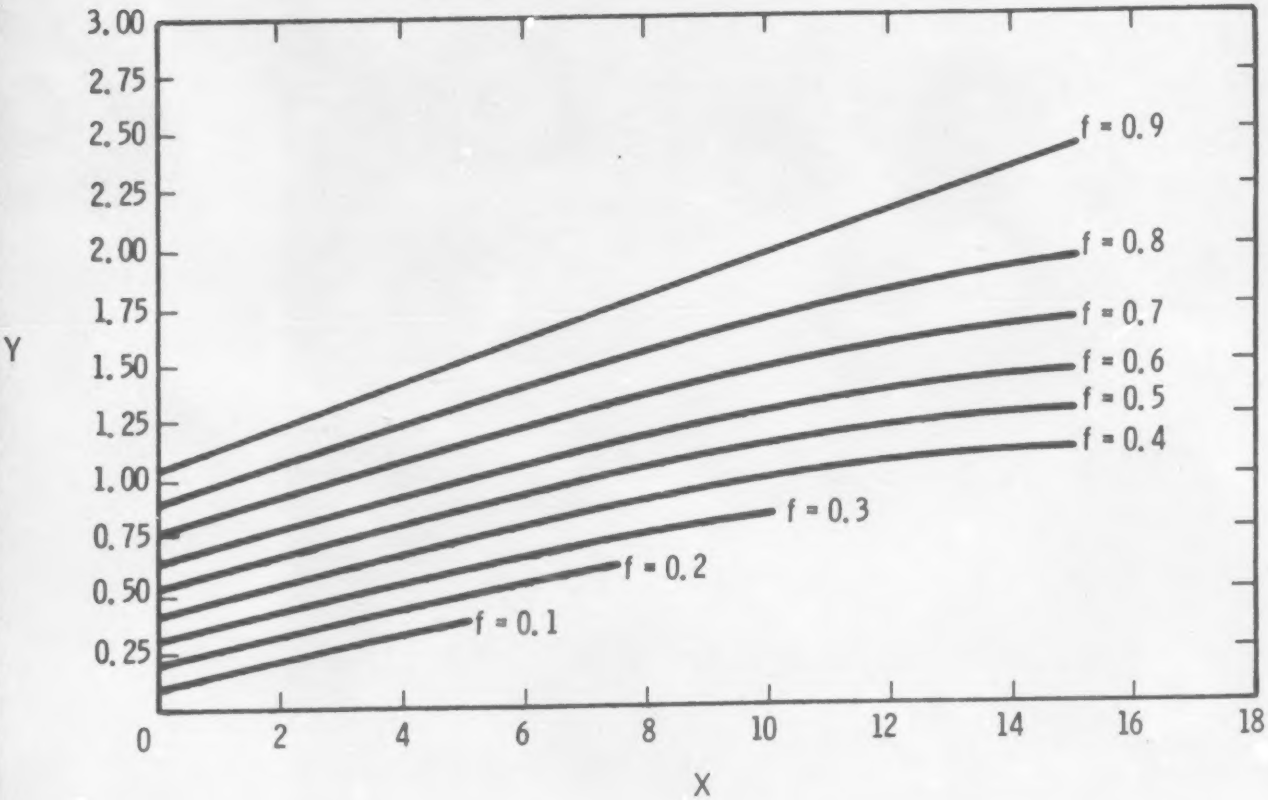

Figure 6-9. f - Chart for Solar Air Heating Systems

Once the X and Y coordinates have been determined for a specific collector area, it is very easy to determine performance for other collector areas using a simple graphical construction. Draw a line on Figure 6-8 or 6-9 between the coordinates (o, o) and (X, Y) for each month. The endpoint of each line determines f for the month for the original collector area. Simply double the length of each line and read off f for a system with twice the collector area, etc. Worksheet TA-3 has room for tabulating the system performance for three different collector areas.

EFFICIENCY DATA FOR AIR HEATING COLLECTORS

The performance data for solar collectors which have air as the working fluid, is often presented in a different way than is the data for water type collectors. For a water collector, the performance data usually is a plot of collector efficiency plotted versus the term $(T_{IN} - T_A)/H_T$ where

T_{IN} = the collector water inlet temperature (^{o}F)
T_A = the outside ambient air temperature (^{o}F)
H_T = incident solar flux on the collector surface (BTU/(hr-ft^2))

The air collector data is usually plotted in the form collector efficiency versus the term $(T_{out} - T_A)/H_T$, where

T_{out} = the collector air outlet temperature (^{o}F)

while T_{out} and H_T are the same as above. This difference in notation is not trivial. The slope (FRCUA) and the intercept (FR ($\tau\,\alpha$) you will need for the F-chart methodology in Chapter VI must be corrected before they can be used. The procedure is to read off the slope and intercept as usual and solve the formulas below for the corrected values, i.e.,

$$FR(\tau\,\alpha)^{IN} = \frac{FR(\quad \alpha)^{out}}{\left[1.0 + \dfrac{FR(UL)^{out}}{1.08\,\dfrac{SCFM}{ft^2}}\right]}$$

$$FR(UL)^{IN} = \frac{FR(UL)^{out}}{\left[1.0 + \dfrac{FR(UL)^{out}}{1.08\,\dfrac{SCFM}{ft^2}}\right]}$$

where

$FR(\tau\alpha)^{IN}$ = the desired intercept value in the T_{IN} notation

$FR(\tau\alpha)^{out}$ = the available intercept in the T_{out} notation

$FR(UL)^{IN}$ = the desired slope in the T_{IN} notation

$FR(UL)^{out}$ = the available slope in the T_{out} notation

$\frac{SCFM}{ft^2}$ = air flow rate through the collector associated with the test conditions for the data available in standard cubic feet per minute per square foot of collector area.

SIZING AND COLLECTOR EFFICIENCY

The size of a collector array depends to a large extent on the "efficiency" of a collector. Collector efficiency is the ratio of the heat input to the collector over the heat output to the rest of the solar system.

$$\text{Collector Efficiency} = \frac{\text{Btu output}}{\text{Btu input}}$$

Inefficient collectors are exposed to a lot of potential heat energy, but fail to absorb and/or transmit much of that heat to the rest of the system. Highly efficient collectors absorb and transmit most of the heat energy to which they are exposed. The maximal efficiency of a collector usually ranges from 80 to 90 percent, and is indicated in the manufacturers specifications. The more efficient a given collector, the smaller the collector array necessary to satisfy the building heat load.

The extent to which maximal collector efficiency is achieved is influenced by the tilt angle of the collector array. Maximal collector efficiency is achieved only when the tilt angle optimal for a given system is used. When non-optimal tilt angles are used, the array delivers only a percentage of the heat it could potentially deliver if an optimal tilt angle were used. For example, consider a collector array which delivers 53,000 Btu/hr, when the tilt angle is optimal. If the tilt angle is 15° less than optimal, the array delivers only 90% of the 53,000 Btu/hr, or 47,700 Btu. If this non-optimal tilt angle must be used, collector array area should be increased to satisfy the 53,000 Btu/hr heat load.

ASSIGNMENT SHEET SB-8-6

TILT ANGLE, ORIENTATION AND COLLECTOR EFFICIENCY

Answer the study questions below.

a. What is the optimal collector tilt angle, relative to latitude, for:

space heating only __________
space heating-cooling only __________
domestic hot water heating only __________

b. Because of architectural restraints, a collector array for hot water heating in Griffin, Georgia (latitude 33°) must be tilted at 28°. At that angle, what will be the efficiency of the array, relative to maximal efficiency?

c. To what extent must the above array size be increased so that maximal array efficiency is achieved?

d. Relative to optimum efficiency, what is the efficiency of a collector tilted 30° east of south? __________

To what extent must array size be increased to compensate for this loss of efficiency?

SIZING STORAGE UNITS AND OTHER COMPONENTS

There are many different ways to size components of solar systems. For many components, manufacturers specifications indicate appropriate sizing procedures, or the manufacturers size the components themselves, given certain system dimensions.

The table below indicates rules of thumb for sizing various aspects of solar systems. These rules of thumb are useful for quickly estimating the sizes of system components.

Rules of Thumb for Sizing

SOLAR AIR HEATING SYSTEMS	
Collector slope	Latitude + 15°
Collector air flow rate	1.5 to 2 cfm/ft^2 of collector
Pebble-bed storage size	½ to 1 ft^3 of rock/ft^2 collector
Rock depth	4 to 8 feet in air flow direction
Pebble size	3/4" to 1" concrete aggregate
Duct insulation	1" fiberglass minimum
Pressure drops:	
Pebble-bed	0.1 to 0.3" W.G.
Collector(12-14 ft lengths)	0.2 to 0.3" W.G.
Collector(18-20 ft lengths)	0.3 to 0.5" W.G.
Ductwork	∿0.08" W.G./100' duct length
SOLAR HYDRONIC HEATING/COOLING SYSTEMS	
Collector slope	Latitude +15°
Collector flow rate	∿0.02 gpm/ft^2 of collector
Water storage size	1.5 to 2.5 gallons/ft^2 of collector
Pressure drop across collector	0.5 to 10 psi/collector module
SOLAR DOMESTIC HOT WATER HEATING SYSTEMS	
Preheat tank size	1.5 to 2.0 times DHW auxiliary tank size

However, in some cases, more precise calculations are necessary for final sizing. The following pages review procedures associated with the sizing of heat storage units. Calculating heat absorption by storage material and calculating exact heat storage size are reviewed.

ASSIGNMENT SHEET SB-8-8

Answer the study questions below.

a. A 300 square foot liquid collector array is installed in a house. What would be the largest and the smallest storage area necessary?

b. In the house described above, the overnight heat load in January is 275,000 Btu. Assuming a temperature change of 50° F, what size of storage unit is necessary?

c. In an ideal heat exchanger, how does the temperature of the storage loop liquid leaving the heat exchanger compare with the temperature of the collector loop liquid entering the heat exchanger?

d. What is meant by "approach temperature?" What approach temperature is achieved by most heat exchangers?

e. How is the operating temperature and efficiency of the collector array affected by decreasing approach temperature?

f. What system information must be provided to heat exchanger manufacturers in order for them to be able to size heat exchangers for a given solar system?

ASSIGNMENT SHEET SB-8-10

Answer the study questions below.

a. Why is some type of expansion tank necessary in a liquid solar system?

b. Using the table below briefly describe how each type of expansion tank allows expansion. Mention advantages and disadvantages of each.

	Operation	Advantages and Disadvantages
Open Tank		
Air cushion Tank		
Diaphragm air Cushion Tank		

c. A system is filled with 65 gallons of water at 45° F and is then heated to 155° F. By what amount will the water expand?

d. In the system described in (c), by what amount will the liquid expand if it is 33% ethylene glycol? (maximum design temperature is 200° F)

e. For each of the factors listed below, indicate the conditions which must be met in order to select a heat duct coil:

air velocity across the coil-

supply water temperature-

entering air temperature-

water temperature drop through the coil-

total system air flow rate-

f. If the auxiliary heat unit requires an air flow rate of 1000 cfm, and the face velocity is 400 fpm, what area of duct coil is required?

g. The space heating load in a liquid-to-air system is 68,000 Btuh. If there is a 15° F temperature drop through the heating coil, what volume of water must be pumped from storage?

h. A system has a 1600 cfm flow rate. In the heating coil the entering air temperature is 84° F. Entering water temperature is 150° F, with a flow rate of 7 gpm. What type of heat coil is necessary to satisfy a 78,100 Btuh heat load? (Refer to Table 6-5 in Fundamentals)

SOLAR HEATING SYSTEMS CURRICULUM
UNIT LISTING

PHASE A: BASIC UNDERSTANDING

Unit	Task
SA-1	Explain the value of solar energy and principles of solar radiation.
SA-2	Describe basic solar system components and their functions.

PHASE B: DESIGN

Unit	Task
SB-1	Recommend non-solar energy conservation measures.
SB-2	Select passive solar approaches for new construction.
SB-3	Recommend collectors.
SB-4	Recommend and site the thermal storage unit.
SB-5	Recommend control devices.
SB-6	Recognize and describe modes of solar system operation.
SB-7	Calculate heat load for space or domestic hot water heating.
SB-8	Size solar system components.
SB-9	Perform a solar system economic analysis.
SB-10	Recommend a domestic hot water system.

PHASE C: INSTALLATION

Unit	Task
SC-1	Recommend correct thermal mass for direct gain system; fabricate and install modular wall units for passive solar.
SC-2	Schedule solar installation.
SC-3	Install a liquid storage tank.
SC-4	Site and mount collectors.
SC-5	Install liquid collectors and outside plumbing.
SC-6	Install inside plumbing for collector load side loops.
SC-7	Install controls and wiring.
SC-8	Start up system.

PHASE D MAINTENANCE

Unit	Task
SD-1	Maintain the solar system.
SD-2	Troubleshoot solar system problems

MAJOR BLOCK Solar Systems (Phase B:Design) NAME

TASK Perform a Solar System Economic Analysis

UNIT SB-9 TIME (est.) (act.)

OBJECTIVE(S) The student should be able to:
(1) determine the annual cash flows for solar and non-solar systems
(2) determine the time of payback and positive savings
(3) choose an economical collector area for a particular solar installation

START → W-1 L-1 W-2 L-2 C-1 W-3 L-3 W-4 L-4 C-2 W-5 L-5 C-3

WRITTEN ASSIGNMENT(S)		AUDIOVISUAL(S)	
W-1	Assignment SB-9-1	A-1	
W-2	Assignment SB-9-3	A-2	
W-3	Information Sheet SB-9-1	A-3	
W-4	Assignment SB-9-6	A-4	
W-5	Information Sheet SB-9-2	A-5	
W-6	Assignment SB-9-9	A-6	
W-7		A-7	

LABORATORY ASSIGNMENT(S)		CHECKPOINT(S)	
L-1	Assignment SB-9-2	C-1	Progress check (written quiz)
L-2	Assignment SB-9-4	C-2	Observation
L-3	Assignment SB-9-5	C-3	Test (written)
L-4	Assignment SB-9-7	C-4	
L-5	Assignment SB-9-8	C-5	
L-6		C-6	
L-7		C-7	
L-8		C-8	
L-9		C-9	

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Atlanta, Georgia 30334
Charles McDaniel, State
Superintendent of Schools
1979

No person shall, on the basis of sex, race, national origin or handicap, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity under the direction of the local education agency.

ACTIVITY SEQUENCE SHEET

Activity	Flow Chart Number	Description of Activity
Assignment SB-9-1	W-1	Read Lennox Solar Manual: Economics Introduction (p. 1) and "Energy costs" and "Inflation Rates" (p. 2-3).
Assignment SB-9-2	L-1	Answer study questions on Assignment Sheet SB-9-2.
Assignment SB-9-3	W-2	Read Lennox Solar Manual: Economics "Solar System Costs" (p. 1) and p. 4-6.
Assignment SB-9-4	L-2	Answer study questions on Assignment Sheet SB-9-4.
Progress Check	C-1	Written quiz.
Information Sheet SB-9-1	W-3	Read Information Sheet SB-9-1.
Assignment SB-9-5	L-3	Do activity described on Assignment Sheet SB-9-5.
Assignment SB-9-6	W-4	Read Lennox Solar Manual, Economics, p. 7-10.
Assignment SB-9-7	L-4	Solve the problem described on Assignment Sheet SB-9-7.
Observation	C-2	Observation by teacher of solution to Assignment SB-9-7.
Information Sheet SB-9-2	W-5	Read Information Sheet SB-9-2.
Assignment SB-9-8	L-5	Answer questions on Assignment Sheet SB-9-8.
Assignment SB-9-9	W-6	Read Fundamentals, p. 6-6 to 6-7 (sections on "Life-cycle-costs" and Solcost computer analysis"). Also, review Appendix E in Fundamentals. The purpose of this assignment is to familiarize you with the use of the Solcost procedure, and factors affecting it. You are not expected to learn detailed information about the procedure or how to fill out the information form.
Test	C-3	Written.

Answer the study questions below:

a. If gas costs $0.31/therm, and a gas furnace is 60 percent efficient, what is the energy cost? A therm is 100,000 Btu, and has a volume of about 100 cubic feet.

b. If the furnace described above is 50 percent efficient, what is the energy cost?

c. If electricity for resistance heating costs $0.04 per kWh, what is the energy cost?

d. Assuming a 10 percent annual rate of inflation in natural gas costs, what will be the energy cost in 10 years for the conditions of Problem a (above)?

e. Assuming an 8 percent annual rate of inflation in electricity costs, what will be the energy cost in 10 years for the conditions of Problem c (above)?

f. What is the current cost of natural gas, oil, and electricity in your area?

Gas: ___________/therm

Electricity: ___________/therm

Oil: ___________/gallon

Answer the study questions below:

a. Estimate the cost of a complete solar system which has 450 square feet of collector area.

b. A solar system is estimated to cost $10,200. The owner obtains a 20 year loan with interest at 10 percent and 20 percent required down payment. What is the annual mortgage payment on the loan?

c. The solar system described above is located in an area where property is taxed at 40 percent of its actual value. The tax rate is 41 mills ($41 on every $1,000, or 0.041). What is the annual property tax on the solar system?

d. The annual mortgage payment on a solar system is $1,200 per year with a 10 percent interest rate. When 15 years remain on the mortgage, what amount of that years mortgage payment is interest?

e. The individual who owns the system described above is in a 30 percent tax bracket for federal income tax purposes. What amount of income tax credit will s/he receive for paying the interest on the loan?

f. How does the energy operating cost of a solar system compare to that of a non-solar system?

LEGISLATION AFFECTING SOLAR SYSTEM COSTS

Federal Legislation

The federal government has provided a variety of tax incentives to encourage energy conservation and installation and use of solar systems. To encourage home energy conservation, such as installation of attic insulation or storm windows, homeowners are entitled to a credit of 15 percent of the first $2,000 spent on such measures, with a maximum credit of $300. This means that if you spent $1,000 on buying storm windows for your home, you would receive a $150 (0.15 x 1,000 = 150) tax credit on your income tax.

Use of renewable energy sources is encouraged by a tax credit of 30 percent of the first $2,000, plus 20 percent of the next $8,000 spent on solar, geothermal or wind-powered equipment. The maximum tax credit here is $2,200. This means that if you spent $2,000 on a domestic hot water heating system, you would receive a $600 (2,000 x 0.30 = 600) tax credit.

Both types of tax credits apply to expenses incurred after April 19, 1977. In the case of solar systems, systems being installed in new construction beginning before April 20, 1977, but not occupied before April 19, 1977, qualify for tax credits.

Appendix A of this Information Sheet contains more detailed information about federal tax credits, and a copy of the energy credit form, Form 5695, used to file for tax credits.

State of Georgia Legislation

The State of Georgia has passed a variety of laws encouraging and facilitating the use of solar systems. These laws and sources for information about them are summarized in Table 1.

TABLE 1

GEORGIA STATE SOLAR LEGISLATION

---

(1) Act No. 1030 (1976)
as amended by
Act No. 1309, Laws of 1978

Provide sales and use tax refunds for the purchase of equipment for solar systems payable to the owner of the property to which the system is attached.

Contact

Department of Revenue
Sales Tax Unit
Room 310 Trinity - Washington Bldg.
Atlanta, GA 30334
(404) 656-4071

(2) RES. No. 167 (1976)

Enabled constitutional amendment authorizing governing authority of any county or municipality to exempt the value of a solar system from ad valorem property taxation. Taxing authority must act before July 1, 1986.

Contact

Relevant City Council or
County Board of Supervisors

(3) ACT 1446, Laws of 1978

Provides procedures for the creation of voluntary solar easements and makes them subject to the same conveyancing and instrument recording requirements as other easements.

Contact

Relevant Clerk or Recorder

It should be noted that Act No. 1309 (1978) allows tax exemption for active system components and for passive solar system measures that are unique to the passive solar design of the house, and would not be included in ordinary non-solar residences. For example, the cost of heat-absorbing walls may be exempt from sales taxes only if materials used to build the wall are specially chosen to absorb heat. The cost of an ordinary wall which also absorbs solar heat is not tax exempt.

Exemption of the value of a solar system from ad valorem property taxation is determined by local authorities. A partial list of counties/area currently allowing such exemptions includes:

Barrow
Binhill
Chatham
Clark
Clayton
Cobb
Coweta
DeKalb
Hall
Moscogee
Rockdale
Spaulding
Thomas
Walker
Walton
City of Atlanta

More areas are expected to approve this exemption, so local authorities should be consulted.

Laws regarding solar easements protect solar system owners from losing access to solar energy. For example, if a tall apartment building is built directly south of a solar residential installation, the apartment building may block the solar energy needed to power the system. A solar easement is an agreement between neighboring landowners which guarantees access to solar energy by a solar system owner.

Publication 903

Energy Credits for Individuals

1979 Edition

For use in preparing
1978 Returns

Department
of the
Treasury
**Internal
Revenue
Service**

Introduction

Congress has provided tax incentives to encourage energy conservation and the development of alternate energy sources. This publication explains the new tax credits that may be claimed by individuals who installed energy-saving components or solar, geothermal, or wind-powered equipment in their homes after April 19, 1977. For solar, geothermal, or wind-powered equipment, the credit is also available for installations in connection with construction or reconstruction of dwellings before April 20, 1977, provided the original occupancy by the taxpayers began after April 19, 1977.

You claim the credits on line 45 of your Form 1040 for 1978. The amount of credit is computed on Form 5695, which you attach to your return. All eligible expenditures from April 20, 1977, through the end of 1978 are included in computing your credit for 1978. For this purpose, expenditures are generally treated as made when the original installation is completed. You may not amend a 1977 return to claim an energy credit for that year. You may not claim an energy credit on Form 1040A.

Fiscal year return. If you file your return on a fiscal year basis, you may not take the credit until your first tax year beginning after 1977. Your eligible expenditures, however, from April 20, 1977, through the end of your fiscal year may be combined in determining your energy credit for the first tax year.

Two distinct energy credits make up the residential energy credit, each with its own conditions and limitations. These credits are based on:

1) Expenditures for home energy conservation; and
2) Expenditures for renewable energy source property.

Residential Energy Credit

The residential energy credit is made up of the ***credit for energy conservation expenditures*** (15% of the first $2,000 spent on components to conserve energy, or a maximum credit of $300) plus the ***credit for renewable energy source expenditures*** (30% of the first $2,000 plus 20% of the next $8,000 spent on solar, geothermal, or wind-powered equipment, or a maximum credit of $2,200).

The credit is based on the cost of items installed after April 19, 1977, and before January 1, 1986, regardless of when the items were actually purchased. However, solar, geothermal, or wind-powered items that were installed in a newly constructed or reconstructed residence before April 20, 1977, will qualify for the credit if the residence was first occupied by the taxpayer after April 19, 1977. The cost of qualifying items includes the cost of their original installation.

Your residential energy credit must amount to at least $10 in any one year before it may be claimed. This $10 minimum applies ***before*** you consider the limitation to tax described in the following paragraph. The minimum applies to either joint or separate returns.

The credit may not exceed the amount of tax for which you are otherwise liable. Specifically, it is limited to the tax on line 37, Form 1040, minus the credits on lines 38 through 44, Form 1040.

Carryover of unused credit. You may carry over an unused credit (that you may not use because it exceeds your tax liability) to the next tax year. An unused credit may continue to be carried over to later tax years through 1987. (For a fiscal year filer, an unused credit may be carried over through the fiscal year beginning in 1987.)

You must reduce the basis of your residence by the amount of residential energy credit allowed, if the items for which the credit is taken are properly added to the basis of the residence.

Both owners and renters of dwellings are eligible for the credit, provided they actually pay for the qualifying items.

Stockholders of cooperative housing corporations and owners of condominium units may claim a credit based on their allocable share of qualifying expenditures made by the cooperative housing corporation or condominium management association for the benefit of the common owners. For a stockholder of a cooperative housing corporation, the allocable share of the cooperative's expenditures is proportionate to the stockholder's share of the cooperative's total outstanding stock.

If you own or rent your residence jointly with others, the overall limits on qualifying expenditures apply to the combined expenditures of all the owners or renters. If the actual amount spent is greater than the limits, the maximum credit must be apportioned to the joint owners or renters based on the portion of the total expenditures that each contributed. The fact that one joint occupant may be unable to claim all or part of the credit, either because of insufficient tax liability or because of not meeting the $10 minimum credit, has no effect on the computation of the credit for the other joint occupants.

Business use of home. If more than 20% of the use of an energy-conserving or renewable energy source item is for business purposes, you must allocate the expenditure for the item between the business use and the residential use. Only the expenditure allocable to the residential use qualifies for the credit. A swimming pool is not considered used for residential purposes.

Home Energy Conservation Expenditures

You are entitled to a credit of 15% of the first $2,000 you spend on components to conserve energy in your home. You are eligible for the credit when the original installation of the components is completed. The full $2,000 of energy-saving items need not be installed in a single tax year. However, if the qualifying items are installed over a period of more than one tax year, the 15% credit must be claimed for the tax years in which the items are installed, except that expenditures for items installed from April 20, 1977, through the end of 1978 must be combined in computing the 1978 credit. A new $2,000 limit applies to each subsequent principal residence in which you live.

Example 1. In September 1977 you purchase and install $500 of insulation. In February 1978 you install storm windows costing $1,500. If you file your tax returns on a calendar year basis, you may claim a $300 (15% of $2,000) credit on your 1978 return. You may not amend your 1977 return to claim a credit for that year.

Example 2. The facts are the same as in Example 1, but you move to another home in 1979 and spend additional amounts for energy-saving components for the new home. You are eligible for another credit of up to $300 for these expenditures, provided the other conditions are met. You may claim the credit for your additional energy-saving expenditures on the new home, even though the previous owner of your new home had claimed a credit for energy-saving expenditures on it.

Principal residence. The dwelling on which you install the qualified energy-saving components must be your principal residence, must be located in the United States, and must have been substantially completed before April 20, 1977. To qualify for the credit, a dwelling is considered your principal residence beginning 30 days before the date you occupy it.

The energy-saving components you install must be new, must be expected to last at least 3 years, and must meet performance and quality standards to be specified by the Secretary of the Treasury. As of the date of this publication, no performance and quality standards have been issued. However, components purchased before the performance and quality standards are published need not meet these standards.

Qualifying energy-saving components include the following:

Insulation designed to reduce heat loss or heat gain of a residence or water heater

Storm or thermal windows or doors for the exterior of the dwelling

Caulking or weather stripping of exterior doors or windows

Clock thermostats or other automatic energy-saving setback thermostats

Furnace modifications designed to increase fuel efficiency, including replacement burners, modified flue openings, and ignition systems that replace a gas pilot light

Meters that display the cost of energy usage

Additional items, when specified by the Secretary of the Treasury as increasing the energy efficiency of the dwelling. As of the date of this publication, no additional items have been so specified.

Insulation is any item that is specifically and primarily designed to reduce heat loss or gain of a dwelling or water heater. It includes, but is not limited to, materials made of fiberglass, rock wool, cellulose, styrofoam, urea-based foam, urethane, vermiculite, perlite, polystyrene, reflective insulation, and extruded polystyrene foam. It is installed in one of the following applications:

Ceiling insulation, which is installed on the surface of the ceiling facing the building interior or between the heated top living level and the unheated attic space;

Wall insulation, which is installed on the surface or in the cavity of an exterior wall;

Floor insulation, which is installed between the first level heated space of the dwelling and the unheated space beneath it, including a basement or crawl space;

Insulation for hot bare pipes, which is installed around the exterior of the pipes;

Roof insulation, which is placed on the surface of the roof facing the building interior or between a roof deck and its water repellent roof surface;

Exterior insulation for a hot water heater, which is placed around the exterior of the tank; and

Insulation for forced air ducts, which is wrapped around the exterior of the ducts.

Insulation does not include items that are primarily structural or decorative. For example, carpets, drapes, wood paneling, and exterior siding do not qualify although they may have been designed in part to have an insulating effect.

Storm or thermal windows include the following:

1) A window placed outside or inside an ordinary or prime window, creating an air space and providing greater resistance to heat flow and reduced air infiltration.
2) A window with enhanced resistance to heat flow through the glass area by multi-glazing, or with reduced air infiltration through weather stripping. Multi-glazing is an arrangement in which two or more sheets of glazing material are fixed in a window frame to create one or more closed insulating spaces.
3) A window in which the glazed area consists of glass or other glazing materials with heat-absorbing or heat-reflecting properties that reduce the penetration of radiant heat through the window.

Storm or thermal doors include the following:

1) A second door, installed exterior to an existing outer door, to provide greater resistance to heat flow and to reduce air infiltration.
2) A prime exterior door with enhanced resistance to heat flow through the door area because of reduced air infiltration through weather stripping and reduced heat flow through insulating wood or plastic frame material or metal material incorporating thermal breaks.
3) A glass door in which the glazed area is multi-glazed, or consists of glass or other materials with heat-absorbing or heat-reflecting properties that reduce the penetration of radiant heat through the door.

Caulking consists of non-rigid materials placed in the joints of buildings to reduce the passage of air and moisture.

Weather stripping consists of narrow strips of flexible material placed over or in moveable joints of windows and doors to reduce the passage of air and moisture.

Automatic energy-saving setback thermostats are devices designed to reduce energy consumption by regulating the demand on the heating or cooling systems in which they are installed. These thermostats use a temperature control device for interior spaces incorporating more than one temperature control point, and a clock or other mechanism for switching from one control point to another.

Furnace replacement burners are devices for gas or oil-fired heating equipment that:

1) Mix the fuel with air and ignite the fuel-air mixture,
2) Are an integral part of a gas or oil-fired furnace or boiler, including the combustion chamber,
3) Replace an existing furnace burner, and
4) Are designed to achieve a reduction in the amount of fuel consumed as a result of increased combustion efficiency.

Flue opening modifications are dampers that, when installed in the pipe connecting the furnace to the chimney, conserve energy by substantially stopping the flow of air to the chimney when the furnace is not in operation.

Furnace ignition systems are electrical or mechanical devices that, when installed in a gas-fired heating system, ignite the fuel and replace a gas pilot light.

Items that do not qualify for the credit include heat pumps, fluorescent lights, wood- or peat-burning stoves, replacement boilers and furnaces, and hydrogen-fueled equipment.

Renewable Energy Source Expenditures

You may receive an additional energy credit for amounts you spend on solar, wind-powered, or geothermal property for your home. This credit is computed by taking 30% of the first $2,000 and 20% of the next $8,000 of these expenditures. You are eligible for the credit when the original installation of the property is completed. As in the case of energy conservation expenditures, the full $10,000 limit on renewable energy source expenditures may be spread over several tax years. A new $10,000 limit applies for each principal residence you occupy during the period of the credit.

Principal residence. Renewable energy source equipment, such as solar collectors, windmills, or geothermal wells, must be installed for use with your principal residence, which must be located in the United States. However, unlike the credit for energy conservation expenditures, the credit for renewable energy source equipment may be claimed for items installed for use with new, as well as existing, homes.

For purposes of the credit it is immaterial when your home was constructed, as long as the renewable energy source property was installed after April 19, 1977.

However, if renewable energy source property is installed during construction or reconstruction of a residence, it is eligible for the credit when you first occupy the residence as your principal residence. Thus, if the property was installed before April 20, 1977, it may qualify for the credit if you first occupied the residence after April 19, 1977. But if you reoccupy a reconstructed dwelling that you had occupied as your principal residence before the reconstruction, the renewable energy source property is eligible for the credit when it is installed. "Reconstruction" is the replacement of most of a dwelling's major structures, such as floors, walls, and ceilings.

For purposes of the credit, a residence is considered your principal residence beginning 30 days before the date you occupy it.

The renewable energy source property, to qualify, must be new, must be expected to last at least 5 years, and must meet certain performance and quality standards to be specified by the Secretary of the Treasury. As of the date of this publication, no performance and quality standards have been issued. However, the property does not need to meet the standards if it is purchased before the standards are published. The cost of renewable energy source equipment includes labor cost properly allocable to the on-site preparation, assembly, or installation of the equipment.

Renewable energy source property includes the following:

Solar energy equipment for heating or cooling a dwelling or for providing hot water for use within the dwelling

Wind energy equipment for generating electricity or other forms of energy for personal residential purposes

Geothermal energy equipment

Additional devices, when specified by the Secretary of the Treasury, that rely on renewable energy sources for heating or cooling a dwelling or for providing hot water for use within the dwelling. As of the date of this publication, no additional devices have been so specified.

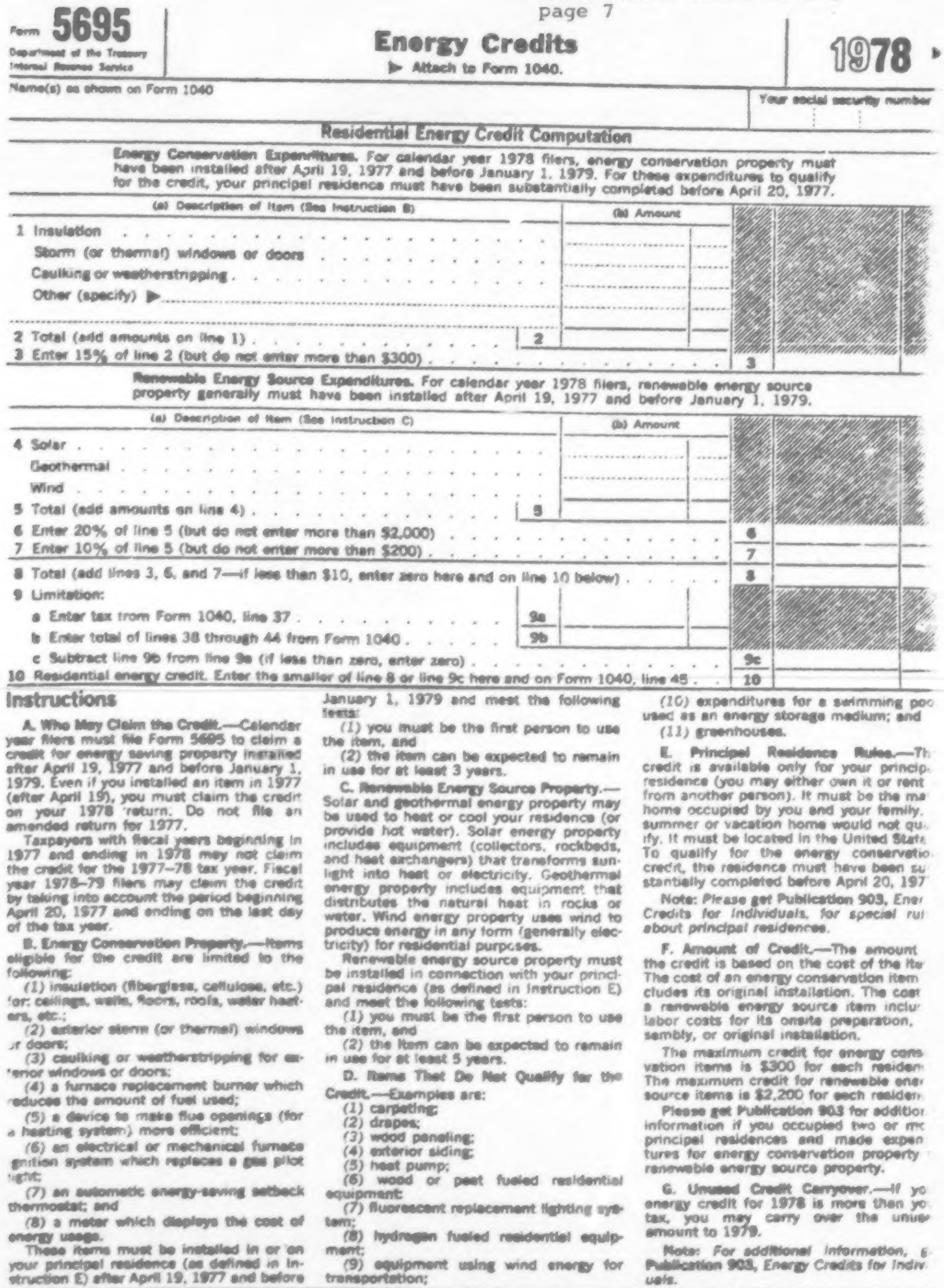
A renewable energy source expenditure does not include any expenditure for a swimming pool used as an energy storage medium. Nor does it include an expenditure for an energy storage medium that has a primary function other than the function of energy storage. It also does not include an expenditure for a heating and cooling system to supplement renewable energy source equipment, if the supplementary system uses a form of energy other than solar, wind, or geothermal.

Solar energy property is equipment that uses solar energy to heat or cool a dwelling or to provide hot water for use within the dwelling. Generally, a solar energy system changes sunlight into heat or electricity through the use of equipment such as collectors (to absorb sunlight and create hot air), rockbeds (to store hot air), thermostats (to activate fans that circulate the hot air), and heat exchangers (to utilize hot air to heat water).

Solar energy property includes "passive" solar systems, "active" solar systems, and combinations of both types. An active solar system is based on the use of mechanically forced energy transfer, for example, using fans to circulate solar heat. A passive solar system is based on the use of conductive, convective, or radiant energy transfer, for example, using portions of the structure as solar furnaces to add heat to the structure. However, for purposes of the credit, materials and components that serve a significant structural function, or are structural components, such as extra-thick walls, windows, skylights, greenhouses, and roof overhangs, are not included as solar energy property.

Wind energy property is equipment that uses wind energy to produce energy in any form for personal residential purposes. Generally, wind energy equipment consists of a windmill that generates electricity and mechanical forms of energy. Equipment that uses wind energy for transporation does not qualify.

Geothermal energy property is equipment that uses geothermal energy to heat or cool a dwelling or to provide hot water for use within the dwelling. This is done by distributing or using geothermal deposits. A geothermal deposit is a geothermal reservoir containing natural heat stored in rocks, water, or vapor. For example, hot springs are a geothermal deposit.



Form **5695**
Department of the Treasury
Internal Revenue Service

Energy Credits

▶ Attach to Form 1040.

1978

Name(s) as shown on Form 1040

Your social security number

Residential Energy Credit Computation

Energy Conservation Expenditures. For calendar year 1978 filers, energy conservation property must have been installed after April 19, 1977 and before January 1, 1979. For these expenditures to qualify for the credit, your principal residence must have been substantially completed before April 20, 1977.

(a) Description of Item (See Instruction B)		(b) Amount		
1 Insulation				
Storm (or thermal) windows or doors				
Caulking or weatherstripping				
Other (specify) ▶				
2 Total (add amounts on line 1)	2			
3 Enter 15% of line 2 (but do not enter more than $300)			3	

Renewable Energy Source Expenditures. For calendar year 1978 filers, renewable energy source property generally must have been installed after April 19, 1977 and before January 1, 1979.

(a) Description of Item (See Instruction C)		(b) Amount		
4 Solar				
Geothermal				
Wind				
5 Total (add amounts on line 4)	5			
6 Enter 20% of line 5 (but do not enter more than $2,000)			6	
7 Enter 10% of line 5 (but do not enter more than $200)			7	
8 Total (add lines 3, 6, and 7—if less than $10, enter zero here and on line 10 below)			8	
9 Limitation:				
a Enter tax from Form 1040, line 37	9a			
b Enter total of lines 38 through 44 from Form 1040	9b			
c Subtract line 9b from line 9a (if less than zero, enter zero)			9c	
10 Residential energy credit. Enter the smaller of line 8 or line 9c here and on Form 1040, line 45			10	

Instructions

A. Who May Claim the Credit.—Calendar year filers must file Form 5695 to claim a credit for energy saving property installed after April 19, 1977 and before January 1, 1979. Even if you installed an item in 1977 (after April 19), you must claim the credit on your 1978 return. Do not file an amended return for 1977.

Taxpayers with fiscal years beginning in 1977 and ending in 1978 may not claim the credit for the 1977–78 tax year. Fiscal year 1978–79 filers may claim the credit by taking into account the period beginning April 20, 1977 and ending on the last day of the tax year.

B. Energy Conservation Property.—Items eligible for the credit are limited to the following:

(1) insulation (fiberglass, cellulose, etc.) for: ceilings, walls, floors, roofs, water heaters, etc.;

(2) exterior storm (or thermal) windows or doors;

(3) caulking or weatherstripping for exterior windows or doors;

(4) a furnace replacement burner which reduces the amount of fuel used;

(5) a device to make flue openings (for a heating system) more efficient;

(6) an electrical or mechanical furnace ignition system which replaces a gas pilot light;

(7) an automatic energy-saving setback thermostat; and

(8) a meter which displays the cost of energy usage.

These items must be installed in or on your principal residence (as defined in Instruction E) after April 19, 1977 and before January 1, 1979 and meet the following tests:

(1) you must be the first person to use the item, and

(2) the item can be expected to remain in use for at least 3 years.

C. Renewable Energy Source Property.—Solar and geothermal energy property may be used to heat or cool your residence (or provide hot water). Solar energy property includes equipment (collectors, rockbeds, and heat exchangers) that transforms sunlight into heat or electricity. Geothermal energy property includes equipment that distributes the natural heat in rocks or water. Wind energy property uses wind to produce energy in any form (generally electricity) for residential purposes.

Renewable energy source property must be installed in connection with your principal residence (as defined in Instruction E) and meet the following tests:

(1) you must be the first person to use the item, and

(2) the item can be expected to remain in use for at least 5 years.

D. Items That Do Not Qualify for the Credit.—Examples are:

(1) carpeting;
(2) drapes;
(3) wood paneling;
(4) exterior siding;
(5) heat pump;
(6) wood or peat fueled residential equipment;
(7) fluorescent replacement lighting system;
(8) hydrogen fueled residential equipment;
(9) equipment using wind energy for transportation;
(10) expenditures for a swimming poo used as an energy storage medium; and
(11) greenhouses.

E. Principal Residence Rules.—Th credit is available only for your princip residence (you may either own it or rent from another person). It must be the ma home occupied by you and your family. summer or vacation home would not qu ify. It must be located in the United State To qualify for the energy conservatio credit, the residence must have been su stantially completed before April 20, 197

Note: *Please get* **Publication 903,** *Ener Credits for Individuals, for special ru about principal residences.*

F. Amount of Credit.—The amount the credit is based on the cost of the ite The cost of an energy conservation item cludes its original installation. The cost a renewable energy source item inclu labor costs for its onsite preparation, sembly, or original installation.

The maximum credit for energy cons vation items is $300 for each residen The maximum credit for renewable ene source items is $2,200 for each residen

Please get Publication 903 for additio information if you occupied two or m principal residences and made expen tures for energy conservation property renewable energy source property.

G. Unused Credit Carryover.—If yo energy credit for 1978 is more than yo tax, you may carry over the unuse amount to 1979.

Note: *For additional information,* **Publication 903,** *Energy Credits for Indiv uals.*

Note: This facsimile is a copy of Form 5695 and should not be used for purposes of filin one's taxes. Energy tax credits should only be claimed on the official Form 5695.

Discussion of solar system economics requires information about local economic and financial variables. You should be able to discuss the local availability of mortgage money for solar systems, and the mortgage interest rate. Local banks or mortgage companies can be contacted for this information. You should be familar with costs for insuring solar systems, which can be obtained from local insurance companies. Finally, you should be able to cite local property tax rates on solar systems, or whether they are exempt from local property taxes, as is the case in some areas of Georgia. The local revenue or tax collection office will be able to provide this information.

Using the sources suggested above, obtain information about local mortgages, insurance, and property taxes pertaining to solar installations. You may want to work with other students in obtaining this information. In the table below, describe the information you find, and where you obtained it.

	Information	Source
Insurance		
Mortgages		
Property taxes		
Other Information		

EXAMPLE

A building in Podunk, U.S.A., has an annual space heating load of 100 m Btu and water heating load of 15 m Btu. A solar system for the building having 400 ft^2 of collector is calculated to provide 50 percent of the annual heating load. Electricity at 3¢/kWh is available and electric auxiliary heating is the only basis on which a loan can be secured.

The terms of the loan are 20 years at 9 percent with 20 percent downpayment. Property tax amounts to 2 percent on one-half the market value of the system, insurance is 0.5 percent of installed cost and the owner's income tax bracket is 30 percent for federal and 10 percent for the state income tax return. The electricity to operate the solar system is 5 percent of the total solar energy delivered as useful heat, and maintenance cost is $100 for the first year.

Electricity cost is estimated to escalate at 7 percent per year and general inflation rate will probably remain at 6 percent for the forseeable future. Determine the annual cash flow for the owner of the solar system for the next 20 years. Also, do an economic summary for the given collector area.

LIFE-CYCLE COST ANALYSIS
LCA-1 WORKSHEET — BASIC DATA

BUILDING DATA

Line 1. Building Annual Heat Load
(from Col. C Total of Step 2A Worksheet in EQUIPMENT SELECTION Section) .... ______ mBtu

Line 2. Hot Water Load
(from Col. D Total of Step 2A Worksheet in EQUIPMENT SELECTION Section) .... ______ mBtu

Line 3. Total Annual Heating Load
(Line 1 ______) + (Line 2 ______) = ... ______ mBtu

SOLAR SYSTEM DATA

Line 4. Collector Area
(from Line 7 of Step 2B Worksheet in EQUIPMENT SELECTION Section) .... ______ sq. ft.

Line 5. Fraction of Annual Heating Load Carried by Solar
(from Line 14 of Step 2B Worksheet in EQUIPMENT SELECTION Section) .... ______ %

Line 6. Unit Cost of Solar System Installed .... ______ $/sq. ft.

Line 7. Installed Cost of Solar System:
(Line 4 ______) x (Line 7 ______) = ... ______ $

Line 8. Type of Auxiliary Fuels:
8a. Space ______ 8b. Hot Water ______

Line 9. Efficiencies of Auxiliary Fuels:
9a. Space ______ % 8b. Hot Water ______ %

Line 10. Auxiliary Fuel Costs (from Figs. 1 & 2):
10a. Space ______ $/mBtu 10b. Hot Water ______ $/mBtu

FINANCIAL DATA

Line 11. Terms of Loan: Years ______ Interest Rate ______ %

Line 12. Down Payment on Loan: (______ %) x (Line 7 ______) = ... ______ $

Line 13. Amount of Loan: (Line 7 ______) — (Line 12 ______) = ... ______ $

Line 14. Annual Mortgage Payment:
(Factor from Fig. 4 ______) x (Line 13 ______) = ... ______ $/year

TAXES AND INSURANCE

Line 15. Property Tax:
15a. Ratio of Taxable Value to Installed Cost ______ %
15b. Property Tax Rate ______ %
15c. Property Tax:
(Line 7 ______) x (Line 15a. ______) x (Line 15b. ______) = ... ______ $/year

Line 16. Income Tax Rate:
16a. Federal Tax Rate ______ %
16b. State Tax Rate ______ %
16c. Effective Income Tax Rate:
(Line 16a. ______) + (Line 16b. ______) — [2 x (Line 16a. ______)
x (Line 16b. ______)] = ... ______ %

Line 17. Insurance:
(Line 7 ______) x (Insurance Rate ______) = ... ______ $/year

OPERATION AND MAINTENANCE

Line 18. First Year Operating Cost:
18a. Annual Solar Heat Supplied:
(Line 5 ______) x (Line 3 ______) = ______ mBtu
18b. Fraction of Solar for Electricity ______ %
18c. Operating Cost:
(Line 18a. ______) x (Line 18b. ______) x (Line 10a. ______) = ... ______ $/year

Line 19. First Year Maintenance Cost = ... ______ $/year

NON-SOLAR SYSTEM DATA

Line 20. First Year Fuel Expenses:
20a. Space: (Line 1 ______) x (Line 10a. ______) = ... ______ $/year
20b. Hot Water: (Line 2 ______) x (Line 10b. ______) = ... ______ $/year
20c. Total Fuel Expenses:
(Line 20a. ______) + (Line 20b. ______) = ... ______ $/year

Line 21. First Year Operating Expenses:
(Line 20c. ______) x (______ %) = ... ______ $/year

Line 22. First Year Fuel and Operating Expenses:
(Line 20c. ______) + (Line 21. ______) = ... ______ $/year

LIFE-CYCLE COST ANALYSIS
LCA-2 WORKSHEET — SOLAR CASH FLOWS

KEY:

Annual Mortgage Rate ________ %
(from Line 11)

Auxiliary Inflation Rate ________ %

General Inflation Rate ________ %

Collector Area ________ sq. ft.
(from Line 4)

Solar Fraction of Total Load ________ %
(from Line 5)

System Cost ________ $
(from Line 7)

Down Payment ________ $
(from Line 12)

Col. A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J	Column K	Column L
YEAR	ANNUAL MORTGAGE PAYMENT (from Line 14)	YEARS LEFT ON MORTGAGE	FRACTION OF MORTGAGE AS INTEREST (from Fig. 4)	INTEREST PAID (Col. B x Col. D)	AUXILIARY FUEL COST (See Note 1.)	PROPERTY TAX (See Note 2.)	INSURANCE (See Note 3.)	OPERATING COST (See Note 4.)	MAINTENANCE COST (See Note 5.)	INCOME TAX SAVINGS (Col. E x Line 16c.)	EXPENSE WITH SOLAR (See Note 6.)
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											

Note 1. First year cost:
(Line 3 ________) x (1.0 — Line 5 ________) x (Line 10a. ________)
Second and future years: (Previous Year Cost) x (1 + Fuel Inflation Rate)

Note 2. First Year Cost: (Line 15c.)
Second and Future Years: (Previous Year Cost) x (1 + General Inflation Rate)

Note 3. First Year Cost: (Line 17)
Second and future years: (Previous Year Cost) x (1 + General Inflation Rate)

Note 4. First Year Cost: (Line 18)
Second and Future Years: (Previous Year Cost) x (1 + Fuel Inflation Rate)

Note 5. First Year Cost: (Line 19)
Second and Future Years: (Previous Year Cost) x (1 + General Inflation Rate)

Note 6. First Year Cost:
(Down Payment) + (Col. B) + (Col. F) + (Col. G) + (Col. H) + (Col. I) + (Col. J) — (Col. K)
Second and Future Years: (Cols. B+F+G+H+I+J—K)

LIFE-CYCLE COST ANALYSIS
LCA-3 WORKSHEET — ECONOMIC SUMMARY

KEY:

Fuel Inflation Rate ________%

Col.M	Column N	Column O	Column P	Column Q	Column O	Column P	Column Q	Column O	Column P	Column Q
YEAR	NON-SOLAR SYSTEM	SOLAR SYSTEM								
		COLLECTOR AREA ________ sq ft			COLLECTOR AREA ________ sq ft			COLLECTOR AREA ________ sq ft		
	FUEL PLUS OPERATING EXPENSE (See Note 1.)	EXPENSE WITH SOLAR (From Col. L)	SAVINGS WITH SOLAR (Col. N) — (Col. O)	CUMULATIVE SAVINGS WITH SOLAR (See Note 2.)	EXPENSE WITH SOLAR (From Col. L)	SAVINGS WITH SOLAR (Col. N) — (Col. O)	CUMULATIVE SAVINGS WITH SOLAR (See Note 2.)	EXPENSE WITH SOLAR (From Col. L)	SAVINGS WITH SOLAR (Col. N) — (Col. O)	CUMULATIVE SAVINGS WITH SOLAR (See Note 2.)
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										

Note 1. First Year Cost: (Line 22)
Second and Future Years:
(Previous Year Cost) x (1 + Fuel Inflation Rate)

Note 2. First Year Savings: (Col. P First Year)
Second and Future Years:
(Previous Year) + (Col. P)

MEASURES OF COST EFFECTIVENESS

For the purpose of this analysis, two measures of cost effectiveness were considered:

- o Positive Savings - Year in which solar system first becomes profitable; i.e., the annual conventional fuel bill without solar exceeds the annual fuel bill with solar plus the annual cost for the solar system.
- o Payback - Year in which the compounded net savings equals the remaining principal on the mortgage for the solar system. Net savings are computed with respect to the fuel cost of the conventional backup system.

These measures were considered because they appear to be the measures with the most meaning for an ordinary property owner.

Positive savings will be of primary importance if the decision maker assumes that the unpaid mortgage for the solar system can be recovered upon the sale of the building. Positive savings can be viewed as similar to "dividends" paid on investment or interest paid on savings; however, taxes will not have to be paid on solar dividends, whereas they would have to be paid on income from savings or investment. Thus, the dividends which a solar system might return in the form of savings is a very important factor for a prospective buyer considering his cash flow position. For this reason, one of the cost effectiveness criteria used here is the amount of time needed for the solar system to generate positive savings, or dividends. Figure 1 shows the annual expenses and resulting year of positive savings for an example.

Payback is commonly used by investors to measure when the capital cost has been entirely recovered. Figure 2 illustrates the payback calculation using solar hot water and heat vs electric resistance hot water and heat in Washington, D. C. as an example. Payback is the amount of time needed to accrue an adequate amount of money from fuel savings to pay off the remaining principal on that portion of the mortgage which financed the solar system. This measure of cost effectiveness would be more attractive to a prospective owner who does not believe the remaining equity in the solarsystem could be recovered in a resale. In the analysis, it was assumed that annual savings are applied toward prepayment of the principal on the solar portion of the mortgage. An additional 8½ percent annual interest is collected on the solar savings, 8½ percent being the rate on the mortgage being prepaid. Although it is unclear that the owner would actually prepay his mortgage, this is a useful measure to denote the point in time in which the solar system has compounded enough in savings to pay the remaining investment.

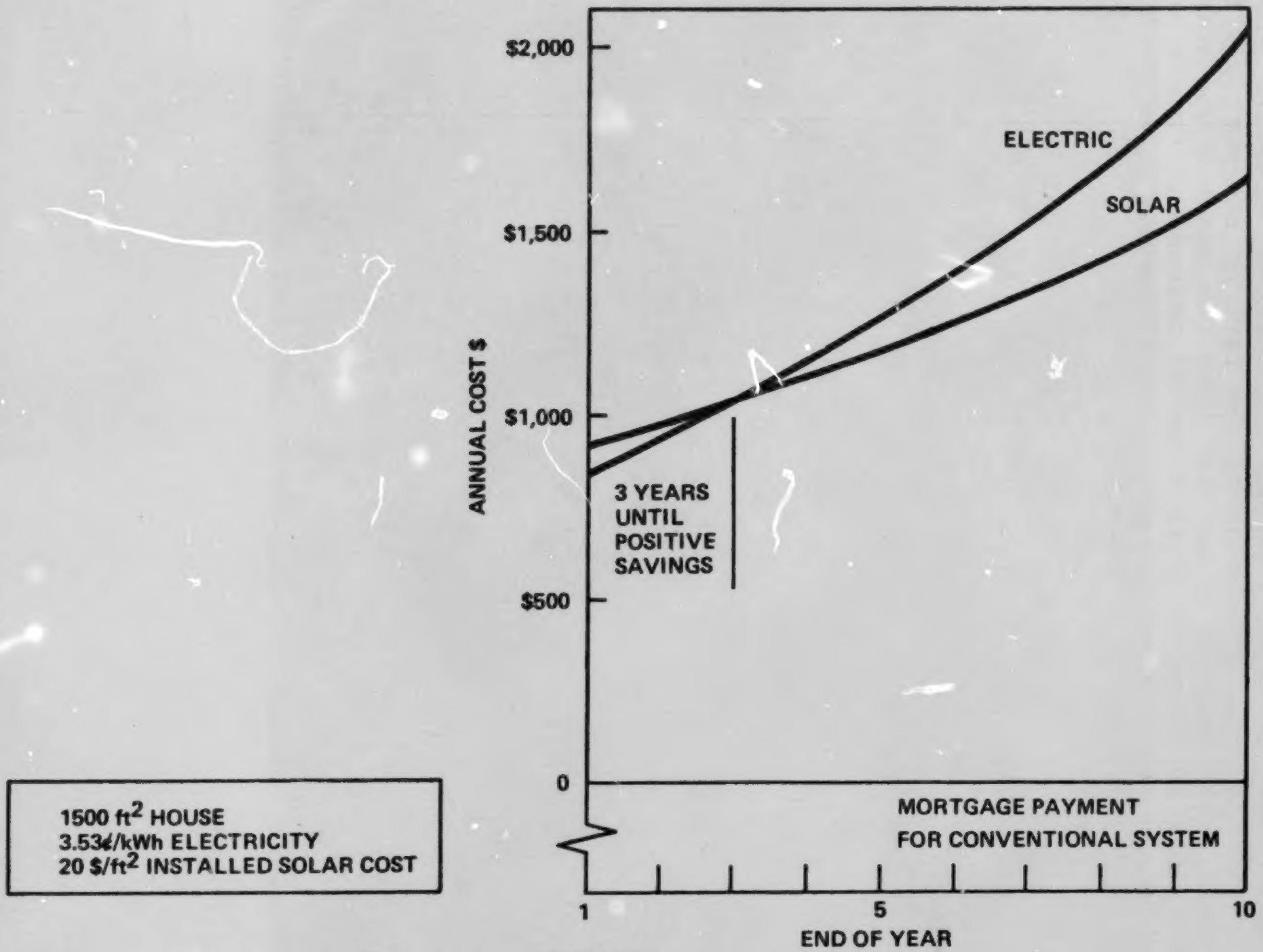


FIGURE 1.
ILLUSTRATION OF ANNUAL EXPENSES FOR SOLAR vs ELECTRIC RESISTANCE

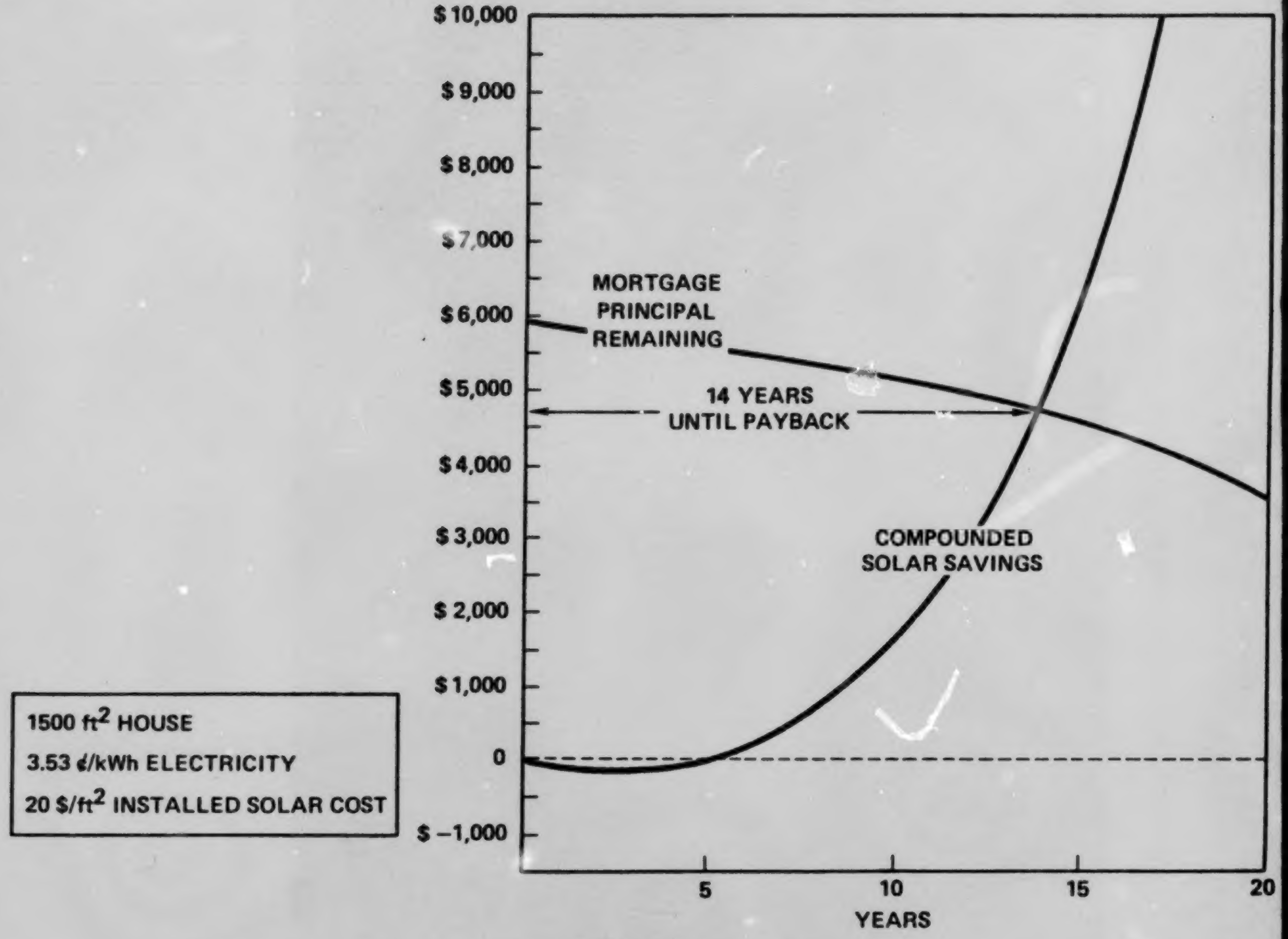


FIGURE 2
ILLUSTRATION OF PAYBACK CALCULATION FOR SOLAR vs ELECTRIC RESISTANCE

a. For the solar system in Podunk, U.S.A. (analysed in Assignment Sheet SB-9-7) identify:

number of years until positive savings _______

number of years until payback _______

b. For the solar system described in the Lennox manual (Economics, p. 8-10), identify:

number of years until positive savings _______

number of years until payback _______

SOLAR HEATING SYSTEMS CURRICULUM
UNIT LISTING

PHASE A: BASIC UNDERSTANDING

Unit	Task
SA-1	Explain the value of solar energy and principles of solar radiation.
SA-2	Describe basic solar system components and their functions.

PHASE B: DESIGN

Unit	Task
SB-1	Recommend non-solar energy conservation measures.
SB-2	Select passive solar approaches for new construction.
SB-3	Recommend collectors.
SB-4	Recommend and site the thermal storage unit.
SB-5	Recommend control devices.
SB-6	Recognize and describe modes of solar system operation.
SB-7	Calculate heat load for space or domestic hot water heating.
SB-8	Size solar system components.
SB-9	Perform a solar system economic analysis.
SB-10	Recommend a domestic hot water system.

PHASE C: INSTALLATION

Unit	Task
SC-1	Recommend correct thermal mass for direct gain system; fabricate and install modular wall units for passive solar.
SC-2	Schedule solar installation.
SC-3	Install a liquid storage tank.
SC-4	Site and mount collectors.
SC-5	Install liquid collectors and outside plumbing.
SC-6	Install inside plumbing for collector load side loops.
SC-7	Install controls and wiring.
SC-8	Start up system.

PHASE D MAINTENANCE

Unit	Task
SD-1	Maintain the solar system.
SD-2	Troubleshoot solar system problems

MAJOR BLOCK Solar Systems (Phase B:Design) NAME

TASK Recommend a domestic hot water (DHW) system

UNIT SB-10 TIME (est.) (act.)

OBJECTIVE(S) Student will be able to:

1) Identify or describe the types of DHW systems available and their operation
2) Select a DHW system for a particular location and application
3) Integrate a DHW system into a space heating system
4) Describe and perform operations for avoiding system problems, such as freezing, overheating, over-pressurization.

START ➔ W-1 ➔ L-1 ➔ W-2 ➔ L-2 ➔ W-3 ➔ L-3 ➔ A-1 ➔ C-1 ➔ L-4 ➔ C-2 ➔ L-5 ➔ C-3

WRITTEN ASSIGNMENT(S)

W-1 Assignment SB-10-1
W-2 Assignment SB-10-3
W-3 Assignment SB-10-5
W-4
W-5
W-6
W-7

LABORATORY ASSIGNMENT(S)

L-1 Assignment SB-10-2
L-2 Assignment SB-10-4
L-3 Assignment SB-10-6
L-4 Job Sheet SB-10-1
L-5 Assignment SB-10-7
L-6
L-7
L-8
L-9

AUDIOVISUAL(S)

A-1 Slide Set SB-10-1
A-2
A-3
A-4
A-5
A-6
A-7

CHECKPOINT(S)

C-1 Progress Check (peer quiz)
C-2 Observation
C-3 Test (written)
C-4
C-5
C-6
C-7
C-8
C-9

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Division of Program Development
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Charles McDaniel, State
   Superintendent of Schools
1979

No person shall, on the basis of sex, race, national origin or handicap, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity under the direction of the local education agency.

ACTIVITY SEQUENCE SHEET

Activity	Flow Chart Number	Description of Activity
Assignment SB-10-1	W-1	Read *Fundamentals*, page 8-1 to 8-3 (up to "Direct heating/pump circulating systems")
Assignment SB-10-2	L-1	Answer study questions on Assignment Sheet SB-10-2
Assignment SB-10-3	W-2	Read *Fundamentals*, page 8-3 to 8-5 (section on "Direct heating/ pump circulating systems")
Assignment SB-10-4	L-2	Answer study questions on Assignment Sheet SB-10-4
Assignment SB-10-5	W-3	Read *Fundamentals*, page 8-5 to 8-6 (sections on "Indirect heating/ circulating systems, Operating cycle") Pay special attention to Figures 8-11 and 8-12.
Assignment SB-10-6	L-3	Answer study questions on Assignment Sheet SB-10-6.
Slide Set SB-10-1	A-1	View Slide Set SB-10-1.
Progress Check	C-1	Peer quiz.
Job Sheet SB-10-1	L-4	Do activity described on Job Sheet SB-10-1.
Observation	C-2	Observation by teacher of outcome of Job Sheet SB-10-1.
Assignment SB-10-7	L-5	Do activity described on Assignment Sheet SB-10-7.
Test	C-3	Written.

a. A solar domestic hot water (DHW) system saves money (more, less) quickly than does a space heating system because ____ ____.

b. Three basic types of solar DHW systems are:

1)

2)

3)

c. List the major components of a typical solar DHW system (see Figure 8-2 in Fundamentals).

d. In the space below, draw a simple thermosiphon system. Label its parts and the directions of fluid flow.

e. A thermosiphon system is an (active, passive) system.

f. Two differences between a thermosiphon DHW system and other DHW systems are that a thermosiphon system is an (active, passive) system and a thermosiphon system requires the storage tank to be located ______________________________.

g. In the table below, list problems with thermosiphon systems, and corrective measures, where available.

Problem	Corrective Measure
1.	1.
2.	2.
3.	3.
4.	4.

h. List below some advantages to thermosiphon DHW systems.

a. In the space below, diagram a drain-down system for a direct heating/pump circulating DHW system. Label each part, and its function. Label the direction of fluid flow.

b. The controls for drain-down should be mechanical and should not rely on electricity because ________________________________
____.

c. In a drain-down circulating system when storage temperature is below _______°F, and collector temperature is above ______°F, and exceeds storage temperature by ______°F, the collector pump should go on.

d. A drain-down system should drain down when the collector temperature sensor indicated the temperature is below ______°F.

e. In a one tank solar DHW system, an auxiliary electric heating element may be installed near the _______ of the tank.

f. What are the advantages of a two tank solar DHW system?

a. What two components are usually added to an indirect heating/circulating system, but not included in the DHW system previously discussed? What is the function of each?

b. The extra pump may be unnecessary if:

1)

2)

3)

c. List below two possible problems with liquid solar DHW systems, and a corrective measure for each.

Problem	Corrective Measure
1)	1)
2)	2)

d. In the collector loop, the pressure relief valve is usually set to discharge at pressures in excess of ______ psi, and must be plumbed to an open drain because __________________ ____.

e. To allow for the pressure build-up and fluid expansion that occur with heating, a storage tank may be equipped with an ______________ tank and a ______________________________.

f. The heat-exchanger used in solar DHW systems must usually be ____________________ to minimize water contamination.

g. List the types of heat exchangers that are most suitable for DHW systems.

h. List below the advantages and disadvantages of using air collectors in solar DHW systems.

Advantage	Disadvantage

i. An air collector DHW system must always use the type of system that has been referred to as an ________________ ____________________ system.

j. In direct and indirect DHW systems, a ________________________ ______________ measures the temperature difference between collector and storage. A difference of _______ °F turns the pump on. When that difference is reduced to _______ °F, the pump goes off.

ANALYZING/DESIGNING A DHW SYSTEM

The following activity should be performed by pairs of students working together. The instructor should check the outcome of the activity.

For labs with existing solar DHW systems:

Analyze the type of DHW system existing in your lab. Make a diagram indicating each system component, its function, and any special characteristics the system may have. Label the type of DHW system.

For labs with solar space heating, but not DHW systems:

Design a DHW system which could be integrated with the existing space heating system. Choose a DHW system that is suitable for the climate in your area, and that is within the budgetary limits of your school. Diagram the total solar system below, labelling each system component and its function.

For labs without a solar system:

Design a DHW system for use in supplying hot water to your lab. Try to make the system as inexpensive as possible, but take into account restraints imposed by the climate and the design of the building. Diagram the system below indicating all the components, their function, and location within the system, and in relation to the construction of your lab.

ASSIGNMENT SHEET SB-10-7

ANALYZING DHW SYSTEMS

Review the DHW system diagrams in Fundamentals. Describe the systems presented in the figures listed below by completing the table.

Figure Number	Direct or Indirect?	Circulating or Thermosiphon?	Heat Exchanger in Collector Loop?	Kind of Freeze Protection	Number of Storage Tanks?
8-1					
8-2					
8-4					
8-5					
8-6					
8-7					
8-13					

Also, try to identify components used in each system to avoid overpressurization or overheating.

SOLAR HEATING SYSTEMS CURRICULUM
UNIT LISTING

PHASE A: BASIC UNDERSTANDING

Unit	Task
SA-1	Explain the value of solar energy and principles of solar radiation.
SA-2	Describe basic solar system components and their functions.

PHASE B: DESIGN

Unit	Task
SB-1	Recommend non-solar energy conservation measures.
SB-2	Select passive solar approaches for new construction.
SB-3	Recommend collectors.
SB-4	Recommend and site the thermal storage unit.
SB-5	Recommend control devices.
SB-6	Recognize and describe modes of solar system operation.
SB-7	Calculate heat load for space or domestic hot water heating.
SB-8	Size solar system components.
SB-9	Perform a solar system economic analysis.
SB-10	Recommend a domestic hot water system.

PHASE C: INSTALLATION

Unit	Task
SC-1	Recommend correct thermal mass for direct gain system; fabricate and install modular wall units for passive solar.
SC-2	Schedule solar installation.
SC-3	Install a liquid storage tank.
SC-4	Site and mount collectors.
SC-5	Install liquid collectors and outside plumbing.
SC-6	Install inside plumbing for collector load side loops.
SC-7	Install controls and wiring.
SC-8	Start up system.

PHASE D MAINTENANCE

Unit	Task
SD-1	Maintain the solar system.
SD-2	Troubleshoot solar system problems

MAJOR BLOCK Solar Systems: Installation (Phase C) **NAME** ______

TASK Recommend Correct Thermal Mass for Direct Gain System; Fabricate and Install Modular Wall Units for Passive Solar Heating

UNIT SC-1 **TIME (est.)** ______ **(act.)** ______

OBJECTIVE(S) The student should be able to:

(1) Apply the principles of passive solar design to fabricate and install correctly:
  (a) a thermosiphon air heater
  (b) a Trombe wall

(2) Can estimate the seasonal heating contribution from a given amount of south glazing, and recommend appropriate amounts of thermal mass for direct gain systems.

START → A-1 → W-1 → L-1 → W-2 → L-2 → C-1 → W-3 → L-3 → C-2 → C-3

WRITTEN ASSIGNMENT(S)

W-1 Information Sheet SC-1-1
W-2 Information Sheet SC-1-2
W-3 Information Sheet SC-1-3
W-4 ______
W-5 ______
W-6 ______
W-7 ______

LABORATORY ASSIGNMENT(S)

L-1 Job Sheet SB-1-1
L-2 Job Sheet SC-1-2
L-3 Job Sheet SC-1-3
L-4 ______
L-5 ______
L-6 ______
L-7 ______
L-8 ______
L-9 ______

AUDIOVISUAL(S)

A-1 Slide Set SC-1-1
A-2 ______
A-3 ______
A-4 ______
A-5 ______
A-6 ______
A-7 ______

CHECKPOINT(S)

C-1 Progress Check*
C-2 Progress Check*
C-3 Unit Test
C-4 ______
C-5 ______
C-6 ______
C-7 ______
C-8 ______
C-9 ______

*See Special Note (next page)

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310

ACTIVITY SEQUENCE SHEET

Activity	Flow Chart Number	Description of Activity
Slide Set SC-1-1	A-1	View Slide Set SC-1-1.
Information Sheet SC-1-1	W-1	Study material on direct gain sizing and contribution.
Job Sheet SC-1-1	L-1	Calculation of Direct Gain Contribution.
Information Sheet SC-1-2	W-2	Thermosiphoning Air Heater Introduction.
Job Sheet SC-1-2	L-2	Thermosiphoning Air Heater Plan.
Progress Check	C-1*	Instructor Observation of L-1,L-2.
Information Sheet SC-1-3	W-3	Trombe Walls.
Job Sheet SC-1-3	L-3	Trombe Wall Plan.
Progress Check	C-2*	Instructor Observation.
Unit Test	C-3	Test.

*Special Note to Students and Instructors UNIT SC-1.

Progress checks for this unit are indicated after each of the Job Sheets SC-1-2, and Job Sheets SC-1-3. Since These Fabrication Projects must be planned individually for each school site, each student should check out each step of the plans made with the instructor.

Once arrangements are made for a fabrication site, each step of the actual fabrication should also be checked by the instructor.

Students will be graded on the quality of their participation in these projects, as part of the Unit Test.

DIRECT GAIN

The following Table, prepared by F. W. Hutchinson, can be used as a design tool to approximate solar heat gain through south-facing windows for the seven-month season. The effects of window type and latitude are relatively small compared with the effects of normal outside air temperature and with the fraction of possible sunshine. The fourth and fifth columns show the net gain of energy (a negative number represents a loss) resulting from the use of one square foot of single or double glass. All 48 cities show net energy gains through the double glass. (The losses for single glass in some cities should be compared with corresponding heat loss through walls.) The approximate seasonal heat gain is the product of the value in column four or five (single or double glass) times the window area, times the number of hours in the heating season. Of course, there will be many days when there will be too much heat to use comfortably. Often, too, other factors such as pulled shades or closed curtains will reduce solar heat gain. Thermal barriers (e.g., insulating shutters) to cover windows at night can greatly reduce heat loss and increase the overall net heat gain. In St. Louis, for example, the net energy gain through south-facing double glass is 16.6 Btu/hr/ft^2 (Column five). Assuming a 200-day heating season, the total seasonal net gain is 200 days/season x 24 hrs/day x 16.6 Btu/hr/ft^2, or about 80,000 Btu/season/ft^2 of glass, comparable to the useful energy output of a good solar heating system.

If heat gain is to be maximized and heat loss minimized during the winter, two layers of clear glass must be used. Although this configuration may transmit considerable heat during the summer, shading devices such as trees, awnings, and venetian blinds can reduce the need for reflecting or heat-absorbing glass. These expensive glasses might be considered for east- or west-facing windows because they are usually more difficult to shade than south-facing ones. (North-facing glass does not require shading except in the southern part of the country where the usn may strike north-facing glass to a significant extent at sunrise and sunset during the summer.)

In order to take full advantage of this "free" heating, and to avoid over-heating, sufficient thermal mass should be provided so as to even out the heating contribution. Recommended amounts of storage capacity are:

30 Btu/ft^2 of glazing/$^{\circ}$F, for surfaces exposed directly to the sun.

120 Btu/ft^2 of glazing/$^{\circ}$F, for surfaces not directly exposed to the sun.

TABLE SC-1-1.1

Solar Heat Gain Through Use of Glass

City	Fraction, F, of maximum possible sunshine.	Normal temperature during seven-month heating season.	Design outside winter temperature.	Net energy gain, Btu/hr/sqft due to use of glass.	
				Single glass	Double glass
1. Albany, N.Y.	.463	35.2	−24	−12.8	5.6
2. Albuquerque, N.M.	.770	47.0	−10	18.05	30.2
3. Atlanta, Ga.	.522	51.5	18	9.0	18.8
4. Baltimore, Md.	.553	43.8	−7	2.0	15.9
5. Birmingham, Ala.	.510	53.8	−10	10.9	19.5
6. Bismarck, N.D.	.546	24.6	−45	−20.1	4.0
7. Boise, Id.	.540	45.2	−28	22.9	16.0
8. Boston, Mass.	.540	38.1	−18	5.2	11.7
9. Burlington, Va.	.419	31.5	−29	−19.5	.9
10. Chattanooga, Tenn.	.503	49.8	−10	5.9	16.7
11. Cheyenne, Wyo.	.666	41.3	−38	5.7	20.3
12. Cleveland, Ohio	.408	37.2	−17	−13.7	3.7
13. Columbia, S.C.	.511	54.0	− 2	11.2	19.6
14. Concord, N.H.	.515	33.3	−35	−12.0	7.4
15. Dallas, Texas	.470	52.5	−3	7.1	16.4
16. Davenport, Iowa	.539	40.0	−27	−3.1	12.8
17. Denver, Colo.	.705	38.9	−29	5.2	21.7
18. Detroit, Mich.	.429	35.8	−24	14.1	44.0
19. Eugene, Ore.	.439	50.2	−4	2.7	13.2
20. Harrisburg, Pa.	.495	43.6	−14	−1.5	12.5
21. Hartford, Conn.	.532	42.8	−18	−.3	14.1
22. Helena, Mont.	.521	40.7	−42	−3.3	12.2
23. Huron, S.D.	.579	28.2	−43	−14.1	8.0
24. Indianapolis, Ind.	.507	40.3	−25	−4.6	11.2
25. Jacksonville, Fla.	.400	62.0	−10	13.9	18.1
26. Joliet, Ill.	.530	40.8	−25	2.9	12.8
27. Lincoln, Neb.	.614	37.0	−29	−2.2	15.3
28. Little Rock, Ark.	.513	51.6	−12	8.5	18.3
29. Louisville, Ky.	.514	45.3	−20	1.5	14.6
30. Madison, Wis.	.504	37.8	−29	−7.6	9.5
31. Minneapolis, Minn.	.527	29.4	−34	−15.74	5.8
32. Newark, N.J.	.550	43.4	−13	1.4	15.5
33. New Orleans, La.	.370	61.6	7	11.7	16.1
34. Phoenix, Ariz.	.590	59.5	16	21.9	27.5
35. Portland, Me.	.525	33.8	21	−7.2	12.0
36. Providence, R.I.	.542	37.2	−17	−6.1	11.3
37. Raleigh, N.C.	.570	50.0	−2	−10.0	20.6
38. Reno, Nev.	.637	45.4	−19	8.6	21.7
39. Richmond, Va.	.594	47.0	−3	8.0	20.2
40. St. Louis, Mo.	.567	43.6	−22	2.6	16.6
41. Salt Lake City, Utah	.592	40.0	−20	0.0	15.9
42. San Francisco, Cal.	.615	54.2	27	17.3	25.7
43. Seattle, Wash.	.340	46.3	3	−7.3	5.2
44. Topeka, Kan.	.613	42.3	−25	3.8	18.4
45. Tulsa, Okla.	.560	48.2	−16	7.4	19.0
46. Vicksburg, Miss.	.447	56.8	−1	−10.7	17.7
47. Wheeling, W.Va.	.408	46.1	−18	3.7	9.0
48. Wilmington, Del.	.558	45.0	−15	3.7	16.9

From *Introduction to Solar Heating and Cooling*.
US/DOE. August, 1978, p. 3 - 30.

EXAMPLE:

Suppose a house has 100 ft^2 of south-facing glazing. How much heat storage capacity should be available?

a) exposed directly to the sunlight?

$$100\ ft^2 \times 30\ Btu/ft^2/^oF = 3000\ Btu/^oF$$

b) not exposed directly?

$$100\ ft^2 \times 120\ Btu/ft^2/^oF = 12000\ Btu/^oF$$

EXAMPLE:

If the amount of south window space is specified, you can use the table of heat capacities in Unit SB-2 to figure out how much heat capacity should be built into the house.

For direct sunlight, a house with 100 ft^2 of south-facing window needs 3000 $Btu/^oF$ storage capacity. (See previous exercise.) If we want to use concrete to provide this, we perform two steps:

(1) Find the cubic feet required:

$$(3000\ Btu/^oF) \div (31.7/ft^3/^oF) \simeq 95\ ft^3 \text{ concrete needed.}$$

(2) Find the area to be covered by 6" thick concrete.

$$\text{Area in } ft^2 = \frac{95\ ft^3}{\frac{1}{2}\ ft.\ \text{thickness}} = 190\ ft^2$$

(3) Select a rectangular size:

$$190\ ft^2 = 12' \times 15'$$

So, a 12' x 15' slab, 6" thick would provide sufficient storage capacity if exposed to 100 ft^2 of south-facing glazing.

DIRECT GAIN

Perform the following calculations:

(1) If a house has 200 ft^2 of south-facing window, how much heat capacity would be recommended?

1) for direct sunlight:

2) for indirect heat storage:

(2) Using the heat capacity table in Unit SB-2, make one recommendation about how to get the necessary capacity.

(3) Repeat exercise (2), making a different recommendation.

(4) Assume a 200 day heating season. Using the table "Solar Heat Gain through Use of South Glass" from Information Sheet SC-1-1, compute the total seasonal net gain in Atlanta for each square foot of south-facing double-glazed window.

INFORMATION SHEET SC-1-2

THERMOSIPHONING AIR HEATERS

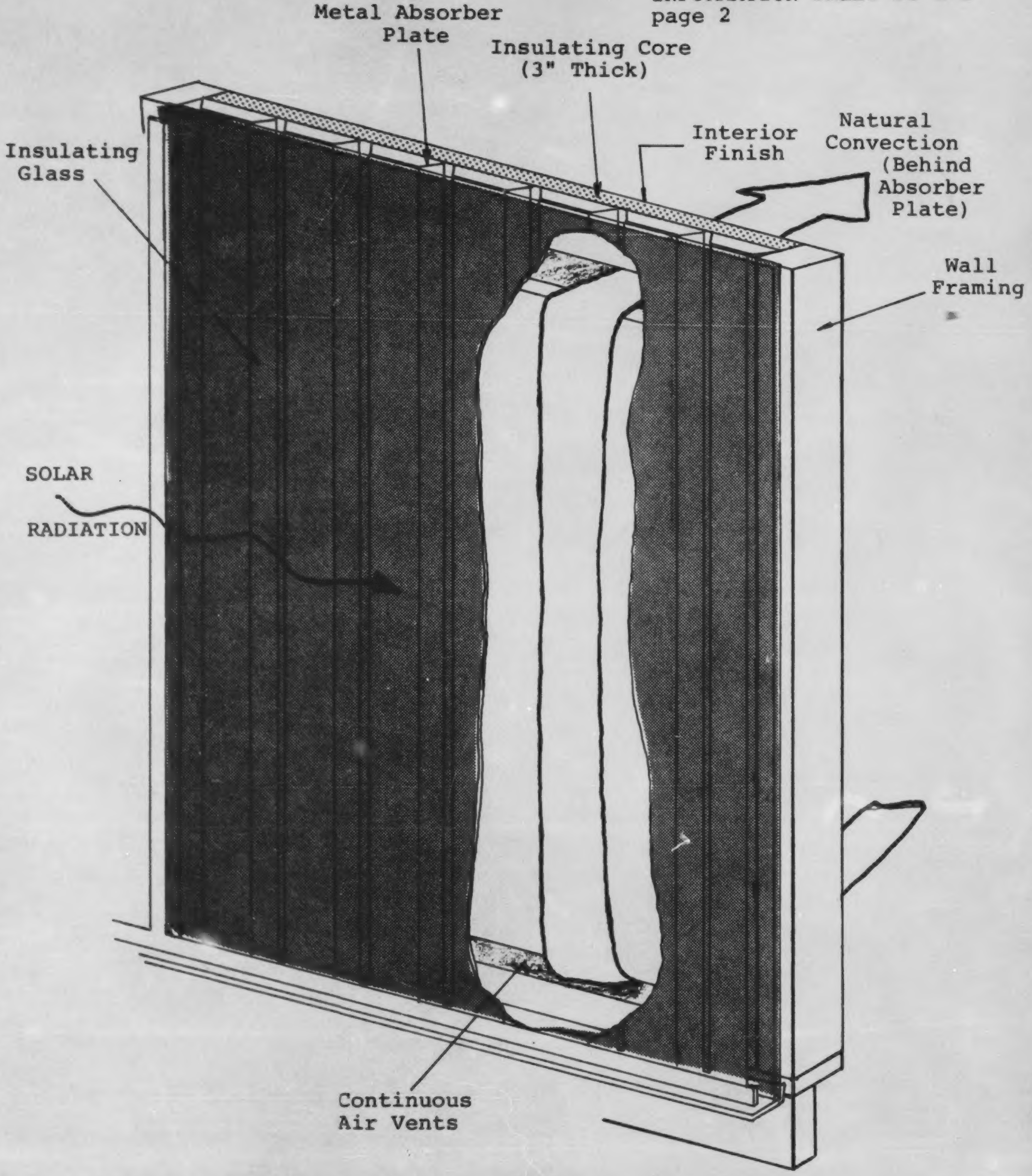
Thermosiphoning panels are air heating solar collectors through which the air flow is powered by pressure differences created between solar heated air and lower temperature room air. A few flat plate collectors now manufactured could, with simple modification, serve as thermosiphoning air heaters. The best design requires a minimum restriction to air flow and a maximum heat transfer surface between absorber and the moving air. These two demands work against each other, in practice. Good cost-effective performance is possible by a thermosiphoning air heater (like the one in the illustration) in most U.S. climates. The illustrated design is well suited for integration into commercial and industrial building types.

Thermosiphoning air heaters are suited to structures where the heating load is large compared to the proposed panel area. This is so that the heat produced will be used, rather than vented to the outside. Schools and low-rise office buildings are such structures. They can certainly be used in homes, but unless thermal storage is built in as well, only a part of the heater's output can be used. This heater, with minor modifications, can be a good application over existing exterior walls.

Heating performance in the thermosiphoning air heater varies, depending on the amount of solar radiation available. Air flow is low to non-existent (Reverse flow is prevented by one-way dampers) at times of little or no sun, but establishes itself rapidly under sunny conditions. Flow rates are generally higher than in Trombe walls; flows of 3 cfm/ft^2 of collector have been measured. The design shown here has a probable maximum rate of 2 cfm/ft^2, with an average temperature rise from an inlet to outlet of $95^{\circ}F$. The resulting 90 Btu/ft^2/hour represents an average collection efficiency similar to that of low temperature flat plate collectors used in standard active system designs.

The total contribution of useful delivered energy varies depending on the size of the heating load and the climate type. Low load structures in warm climates may expect a contribution of 30-40,000 Btu/ft^2/heating season. High load buildings in cold climates may achieve useful delivered contribution of 120,000 Btu/ft^2/heating season.

Improved performance may be achieved by modifications to increase the building's heat storage capacity. Even doubling the thickness of the gypsum board can help. Some research has indicated that improved performance may result from the use of expanded mesh absorbers. Discarded aluminum printing plates have been used as a means of reducing first costs.


Metal Absorber Plate
Insulating Core (3" Thick)
Interior Finish
Natural Convection (Behind Absorber Plate)
Insulating Glass
Wall Framing
SOLAR RADIATION
Continuous Air Vents

THERMOSIPHONING AIR COLLECTOR

THERMOSIPHON AIR PANEL HEATER

(3' x 90")
(Infill panel for a Wood-Framed Bearing Wall)

INSTRUCTIONS:

Follow the guidelines in the sections and sketches below. Suggested installation sites include:

- o as infill panel in on-campus model structure
- o as replacement for conventional wood-framed wall in existing on-campus structure
- o with written permission agreement at nearby local homeowner's or commercial site

This project may best be carried out in co-operation with other students in HVAC and/or with students in building trades curricula.

MATERIALS:

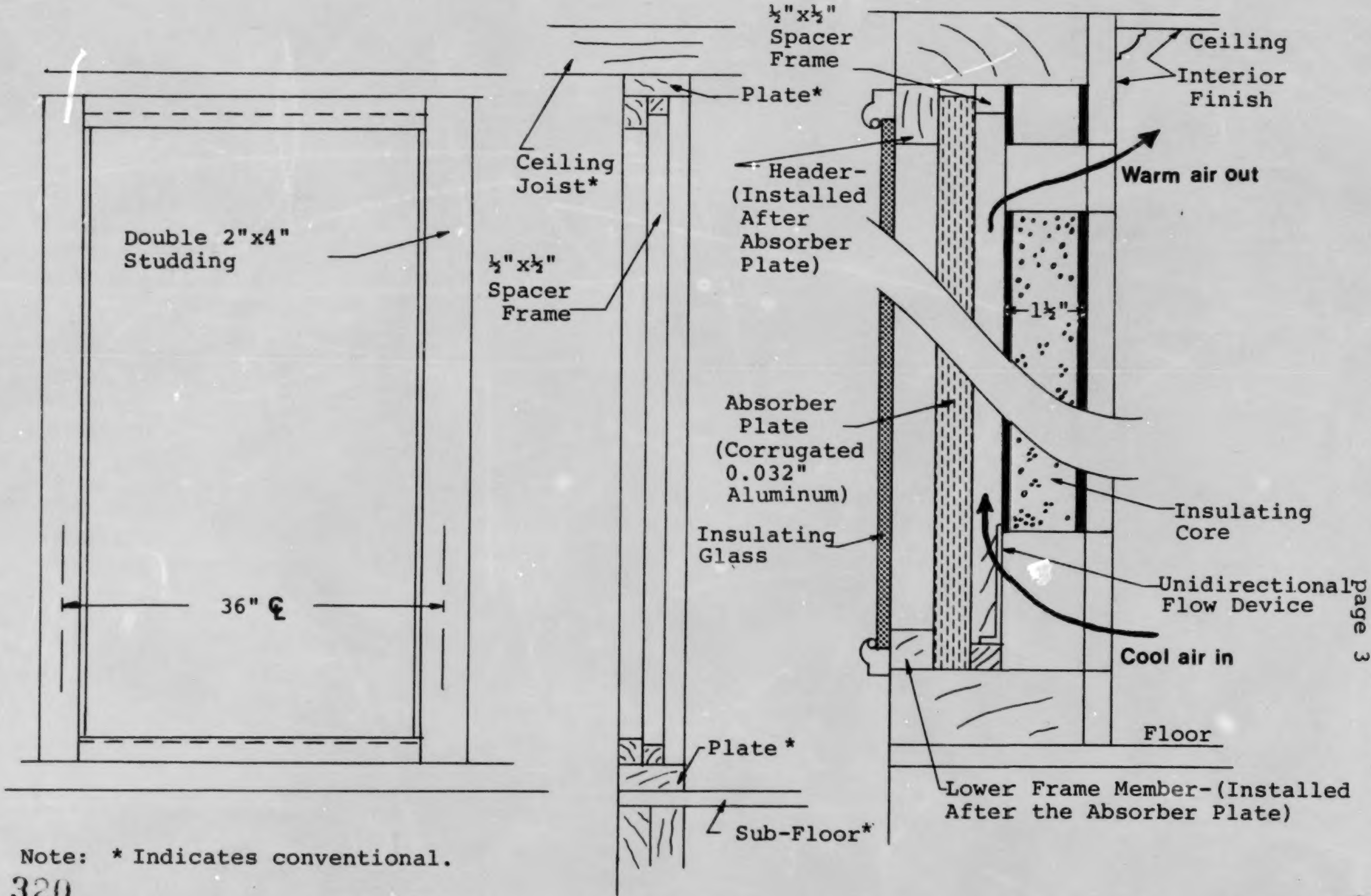
- Exterior Glazing
  - Tempered double-pane insulating glass 34" x 90" (Stocklites manufactured for sliding glass door market)
  - Wood framing (Wood framing serves as necessary insulation between glass and absorber plate)
- Composite Wall Element
  - 8" corrugated .032" aluminum siding fasteners and preformed closure strips
  - Urethane and mineral board roof insulation (3'x4'x1½")
  - Interior finish panel of ½" or 1" Fire Code gypsum board
  - Etching cleaner for siding, primer, NEXTAL brand 'Black Velvet' by 3-M

- Trim and Structural Integration
  - Full width register: standard continuous linear diffuser
  - 1 mil plastic film for one-way dampers
  - Punched or die cut 24-gauge galvanized sheet for frame double-sided adhesive tape

CONSTRUCTION TIPS:

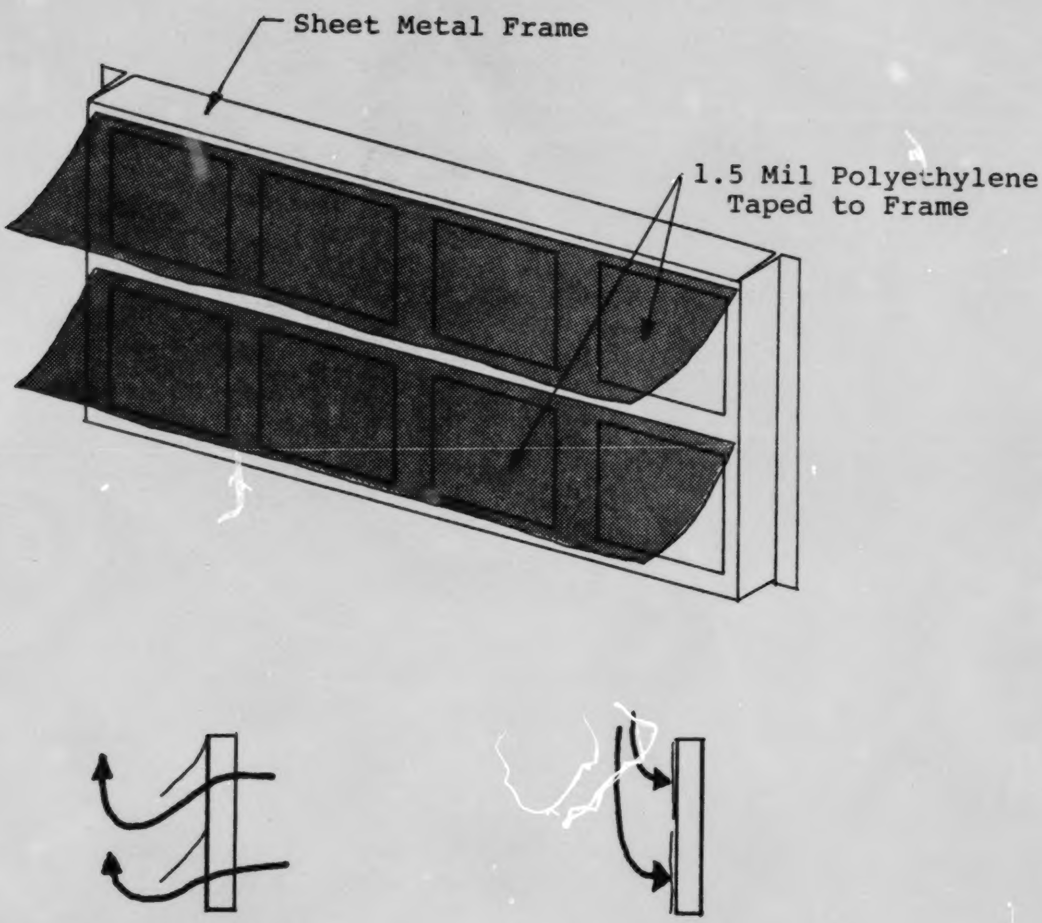
(1) The modular lightweight wall elements are best shop-fabricated, as are the sheet-metal frames for one-way dampers.

(2)
- The glazing and interior trim should be applied after installation in the field.
- Conventional wall framing should be replaced by double 2 x 4 wall studs, 3 feet on center.
- The panel should not be relied upon to provide overall wind bracing of the building frame.
- Electrical wiring should be handled with surface-mounted systems.
- Glazing should be carried out in wood, to minimize the heat flow between the collector panel and the glazing.
- Sealants must be able to withstand high temperatures--higher than those expected in the Trombe Wall.
- Joint between wall element and the abutting construction must be adequately caulked. Care must be taken during construction to see that the interior gypsum board is not damaged.


Double 2"x4" Studding
36" ℄
Ceiling Joist*
½"x½" Spacer Frame
Plate*
Plate *
Sub-Floor*
½"x½" Spacer Frame
Header-(Installed After Absorber Plate)
Absorber Plate (Corrugated 0.032" Aluminum)
Insulating Glass
Ceiling
Interior Finish
Warm air out
1½"
Insulating Core
Unidirectional Flow Device
Cool air in
Floor
Lower Frame Member-(Installed After the Absorber Plate)

Note: * Indicates conventional.

THERMOSIPHONING AIR HEATER


Sheet Metal Frame
1.5 Mil Polyethylene Taped to Frame

Air Flow Permitted

Air Flow Prevented

ONE WAY DAMPERS FOR THERMOSIPHONING AIR HEATERS

INFORMATION SHEET SC-1-3

TROMBE WALLS

The Trombe Wall is a south-facing concrete or masonry wall covered on the exterior by light-transmitting glazing. Its uninsulated interior face is exposed to the living space. The recommended design has vents at the top and bottom to permit air flow by natural convection from the outer surface of the wall into the building. The design illustrated in the figure below is considered cost effective for heating applications in the majority of U. S. climates. The modular dimensions and the particular construction details used here should help to simplify the contractor's tasks of estimation and installation.

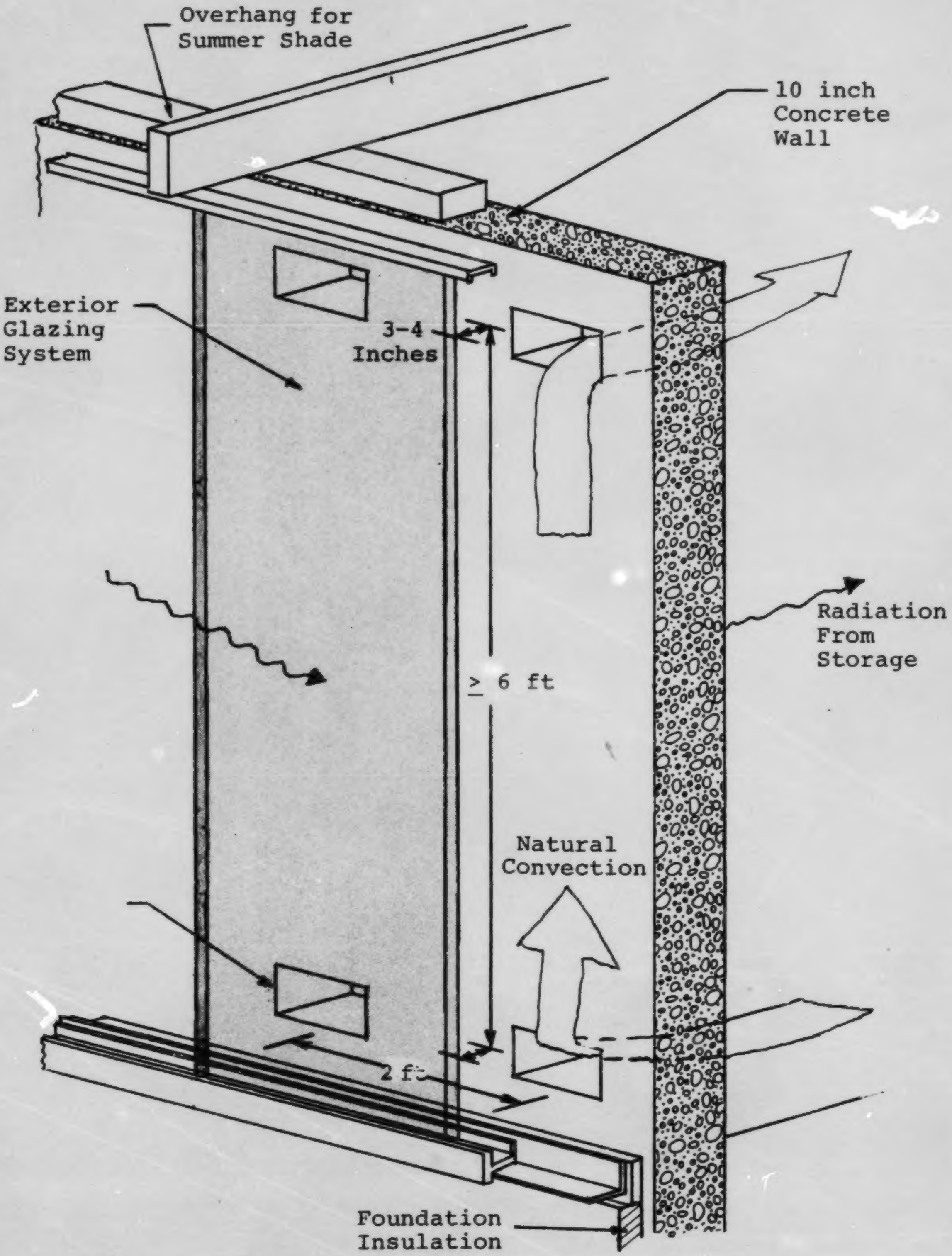
Trombe walls are appropriate for a variety of building types. The thermosiphoning air vents provide control over heat delivery to the space. The wall itself eliminates the excessive glare associated with direct sun. Sun damage to goods and furnishings is avoided, making the wall excellent for heating retail stores and commercial buildings. The structural wall is fire resistant and provides security for warehouses and manufacturing plants as well as structural stability in high rise construction.

Operating costs for the Trombe wall are zero, and little or no maintenance is required. Occasional (every 2 to 4 years) washing of the exterior glazing is advised. Harsh industrial environments may degrade the plastic glazing; 'refinishing' coatings are available from leading manufacturers and may be applied every 3-5 years where necessary.

Thermally, the Trombe wall performs reliably. Heat losses, even under worst conditions, are not very different from conventional commercial construction. The overall U-factor of 0.23 (backflow prevented) means the wall meets ASHRAE 90-75 standards for single family residences located in climates not exceeding 5200 degree days. When solar gains are considered, of course, it is a net heat producer, not a loser.

Solar energy collection takes place at low to moderate temperatures at the surface of a Trombe wall, generally not hotter than 150°F. This provides good efficiency. The vertical south wall orientation enables good winter heating performance and minimize summer overheating concern, except in the deep South. Insulated shutters and high vents in the glazing may be added to this design, to aid in summer performance. Air is delivered to the room at temperatures about 30° F higher than entering room air. Normal air flow is approximately 1 cfm/ft^2.

The interior surface of the wall also delivers heat to the room--usually about eight hours after the heat is absorbed by the surface. Total heat transfer, from both convenction through the vents and from radiation from the wall, is not more than 35 Btu/ft^2/hr.


Overhang for Summer Shade
10 inch Concrete Wall
Exterior Glazing System
3-4 Inches
≥ 6 ft
Radiation From Storage
Natural Convection
2 ft
Foundation Insulation

TROMBE WALL

JOB SHEET SC-1-3

TROMBE WALL

INSTRUCTIONS

Follow the guidelines in the sections and sketches below. Suggested installation sites are those described in Job Sheet SC-1-1. This project must be installed as part of a complete structure for demonstration of its heating performance. This may require its performance as a joint project with students in other curricula.

Materials

- Exterior Glazing
  - Recommended is:

    2-layer fiberglass reinforced, heat-resistant plastic (FILON or KALWALL), large enough to extend above and below the thermal wall

    Aluminum framing, available from manufacturer of the glazing.

    Note: Kalwall Corp.
    P. O. Box 237
    Manchester, NH 03105
    (603) 727-3861

- Inner Thermal Energy Storage Wall
  - High density concrete block and concrete fill, or regular stone concrete (140 lbs/cf), or concrete masonry units and concrete mortar
  - Reinforcing wire, bar, or structural anchors, where necessary
- Backdraft Dampers
  - 1 mil plastic film
  - Double-sided tape
- Trim and Structural Integration
  - Decorative grills for vent holes
  - Wooden blocking to isolate Trombe thermal wall from metal frame of glazing (Important!)

- Rigid insulation between Trombe wall and foundation
- Preformed vinyl or rubber control joints to isolate Trombe wall from adjacent conventional construction

Construction Tips

General:

- The choice between poured concrete, 10" thick, solid masonry units, or filled concrete block depends on local conditions. Some factors to consider are:

  Very rigid and well-reinforced forms would be required to contain the wet concrete mixture and to withstand the hydrostatic pressure until setting occured.

  - Solid concrete masonry units are heavy to manipulate
  - Use of conventional block allows filling to occur after erection of the wall.
  - The foundation directly below the Trombe wall should be protected with a rigid insulation.
  - Installation of the glazing system on job site may be handled by the manufacturer's representative. Care must be taken to isolate its metal frame from the Trombe Wall, as it will tend to draw heat away from the wall.

Vents

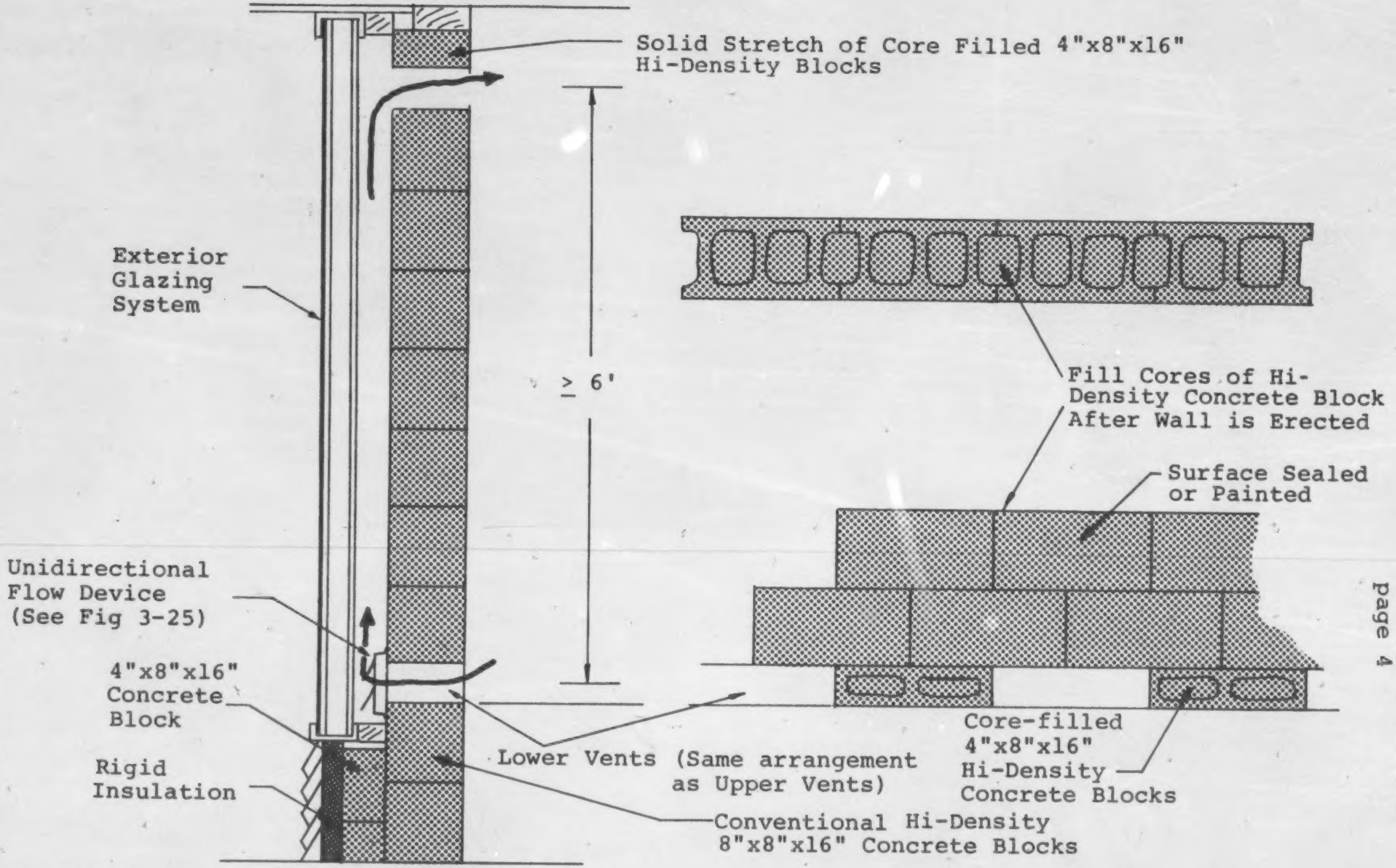
- Walls can be any length, but upper and lower vent holes must be provided on 2-foot centers across the length
- Lower and upper vents should be separated by at least six feet (Important!)
- One-way dampers (backdraft) of very light (1 mil) plastic film should be installed inside the grills on the lower vents.
- Single masonry units may be left out to provide vents, or blocks may be side-laid at reduced distances. 4" x 15" holes on 2-foot centers should be left in the poured wall.

Surface of Wall

- Interior surface of the Trombe wall can be sealed and painted any color. White is a good choice since it has a high emittance rate.
- Sheet materials should not be used.
- Exterior surfaces should be cleaned with a masonry cleaner prior to painting with any dull finish. Flat black is best; red or grey are moderately good.

Glazing and Integration

- Mount the exterior glazing system 3-4" away from the outer concrete surface. When glazing supports are attached to the wall, wood or other insulating material should be used as a separator.
- The thermal wall must be separated from adjacent conventional construction and the ground to prevent loss of stored heat in unwanted directions.


Solid Stretch of Core Filled 4"x8"x16" Hi-Density Blocks
Exterior Glazing System
≥ 6'
Fill Cores of Hi-Density Concrete Block After Wall is Erected
Surface Sealed or Painted
Unidirectional Flow Device (See Fig 3-25)
4"x8"x16" Concrete Block
Rigid Insulation
Lower Vents (Same arrangement as Upper Vents)
Core-filled 4"x8"x16" Hi-Density Concrete Blocks
Conventional Hi-Density 8"x8"x16" Concrete Blocks

TROMBE WALL

SOLAR HEATING SYSTEMS CURRICULUM
UNIT LISTING

PHASE A: BASIC UNDERSTANDING

Unit	Task
SA-1	Explain the value of solar energy and principles of solar radiation.
SA-2	Describe basic solar system components and their functions.

PHASE B: DESIGN

Unit	Task
SB-1	Recommend non-solar energy conservation measures.
SB-2	Select passive solar approaches for new construction.
SB-3	Recommend collectors.
SB-4	Recommend and site the thermal storage unit.
SB-5	Recommend control devices.
SB-6	Recognize and describe modes of solar system operation.
SB-7	Calculate heat load for space or domestic hot water heating.
SB-8	Size solar system components.
SB-9	Perform a solar system economic analysis.
SB-10	Recommend a domestic hot water system.

PHASE C: INSTALLATION

Unit	Task
SC-1	Recommend correct thermal mass for direct gain system; fabricate and install modular wall units for passive solar.
SC-2	Schedule solar installation.
SC-3	Install a liquid storage tank.
SC-4	Site and mount collectors.
SC-5	Install liquid collectors and outside plumbing.
SC-6	Install inside plumbing for collector load side loops.
SC-7	Install controls and wiring.
SC-8	Start up system.

PHASE D MAINTENANCE

Unit	Task
SD-1	Maintain the solar system.
SD-2	Troubleshoot solar system problems

MAJOR BLOCK Solar Systems (Phase C: Installation) **NAME** ______________

TASK Discuss installation barriers and schedule installation

UNIT SC-2 **TIME** (est.) ________ (act.) ______

OBJECTIVE(S) Student will be able to:

1) verbally explain factors limiting the popularity of solar installations
2) integrate the installation of a liquid solar system with construction of a home

START ➡ W-1 → L-1 → C-1 → A-1 → W-2 → L-2 → C-2

WRITTEN ASSIGNMENT(S)

W-1 Assignment SC-2-1
W-2 Assignment SC-2-3
W-3
W-4
W-5
W-6
W-7

AUDIOVISUAL(S)

A-1 Slide Set SC-2-1
A-2
A-3
A-4
A-5
A-6
A-7

LABORATORY ASSIGNMENT(S)

L-1 Assignment SC-2-2
L-2 Assignment SC-2-4
L-3
L-4
L-5
L-6
L-7
L-8
L-9

CHECKPOINT(S)

C-1 Observation
C-2 Test (written)
C-3
C-4
C-5
C-6
C-7
C-8
C-9

Developed by

GEORGIA INSTITUTE OF TECHNOLOGY
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Joe N. Harris

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333

ACTIVITY SEQUENCE SHEET

Activity	Flow Chart Number	Description of Activity
Assignment SC-2-1	W-1	Read *Lennox Solar Manual*, Installation, p. 2-3.
Assignment SC-2-2	L-1	Do activity sheet described on Assignment Sheet SC-2-2.
Observation	C-1	Observation by teacher of activity described on Assignment Sheet SC-2-2.
Slide Set SC-2-1	A-1	View slide set SC-2-1.
Assignment SC-2-3	W-2	Read *Lennox Solar Manual*, Installation, p. 5-7.
Assignment SC-2-4	L-2	Do activity described on Assignment Sheet SC-2-4.
Test	C-2	Written.

REMOVING INSTALLATION BARRIERS

You should already understand how solar heating systems work, and their advantages, relative to conventional heating systems. It is now time to reconsider why solar systems are not more popular. One important factor is the high initial cost of the system. However, the discussion of the economics of solar systems indicated that a well-designed solar system does offer financial gains over the long run, especially in view of the rapidly inflating costs of conventional energy sources.

The reading for Assignment SC-2-1 suggested a variety of other factors that are barriers to solar installations. Let us now consider how we might reduce or remove these barriers. To do this, pretend you are in Atlanta visiting your State Representative. When s/he hears that you are a solar systems installer, s/he says, "Oh, that's very interesting. And how is the solar business these days?" You decide to take the opportunity to tell him/her what legislators could do to encourage use of solar energy. Assume that your Representative has some influence over the financial and insurance community, as well as over the legislative community. What recommendations would you make for legislation that might encourage solar installations and remove installation barriers? Describe your recommendations to a fellow student, and have your instructor observe your presentation.

In the drawings below, indicate when each of the following procedures is performed:

a. construction of storage tank structural base (for basement installation)

b. placement of collectors on roof (when collectors are integrated into the roof)

c. piping to equipment area

d. collector loop leak-testing

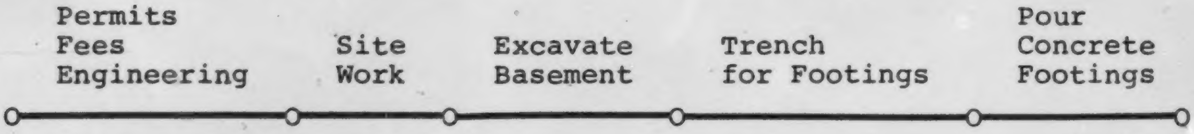
e. storage piping connections

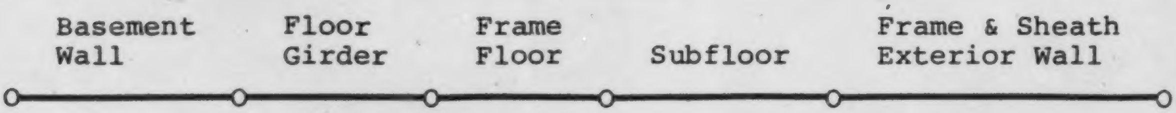
f. installation of control temperature sensors

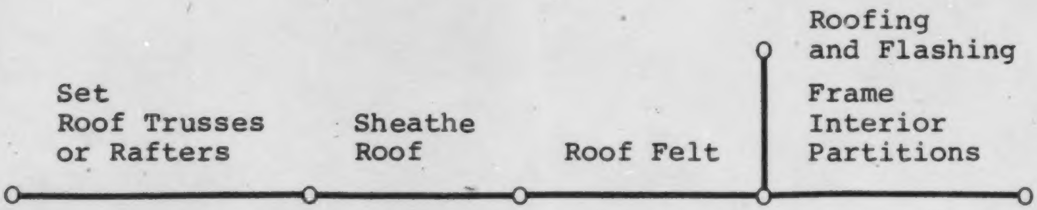
g. control panel installation

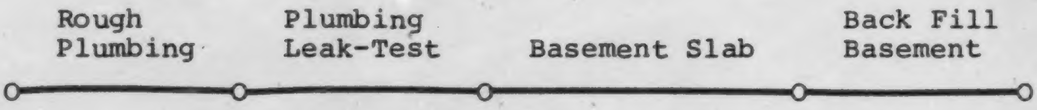
h. piping insulation

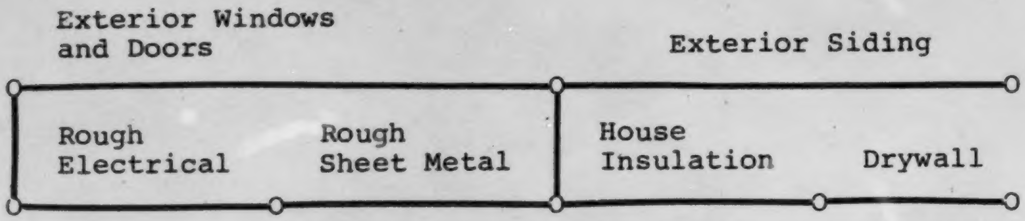
i. installation of preheat coil and domestic hot water tank

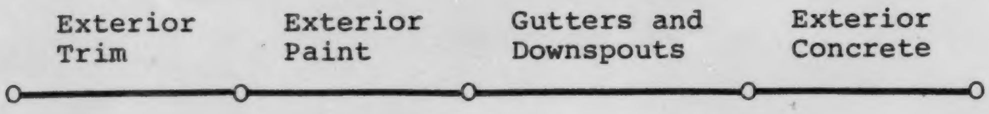

Permits Fees Engineering
Site Work
Excavate Basement
Trench for Footings
Pour Concrete Footings

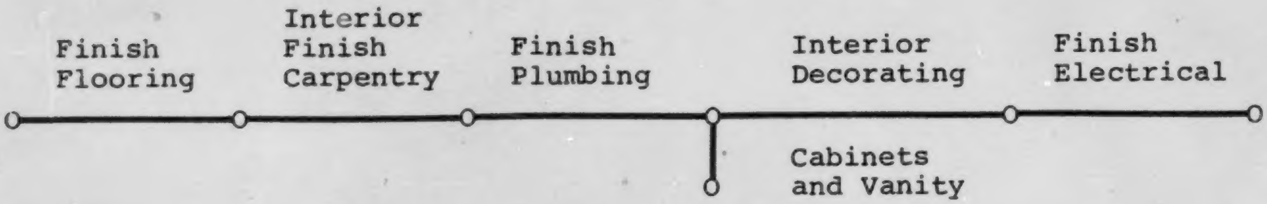

Basement Wall
Floor Girder
Frame Floor
Subfloor
Frame & Sheath Exterior Wall

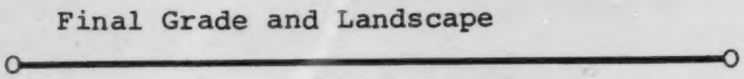

Set Roof Trusses or Rafters
Sheathe Roof
Roof Felt
Roofing and Flashing
Frame Interior Partitions

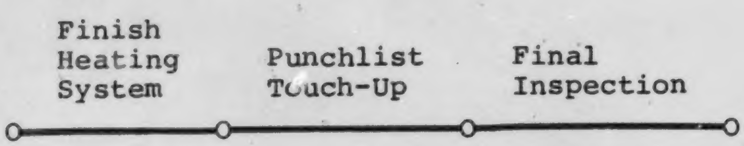

Rough Plumbing
Plumbing Leak-Test
Basement Slab
Back Fill Basement


Exterior Windows and Doors
Exterior Siding
Rough Electrical
Rough Sheet Metal
House Insulation
Drywall


Exterior Trim
Exterior Paint
Gutters and Downspouts
Exterior Concrete


Finish Flooring
Interior Finish Carpentry
Finish Plumbing
Interior Decorating
Finish Electrical
Cabinets and Vanity


Final Grade and Landscape


Finish Heating System
Punchlist Touch-Up
Final Inspection

SOLAR HEATING SYSTEMS CURRICULUM
UNIT LISTING

PHASE A: BASIC UNDERSTANDING

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PHASE C: INSTALLATION

Unit	Task
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SC-8	Start up system.

PHASE D MAINTENANCE

Unit	Task
SD-1	Maintain the solar system.
SD-2	Troubleshoot solar system problems

MAJOR BLOCK Solar Systems Installation (Phase C:) **NAME** ____

TASK Install a liquid storage tank

UNIT SC-3 **TIME** (est.) ____ (act.) ____

OBJECTIVE(S) The student will be able to:

1) safeguard against problems associated with particular types of liquid tanks
2) recommend storage tank location, and identify possible difficulties
3) list steps and considerations in installing the storage tank in a given location, including building a base, leak testing, & insulatin

START → W-1 → L-1 → W-2 → L-2 → C-1

WRITTEN ASSIGNMENT(S)

W-1 Assignment SC-3-1

W-2 Information Sheet SC-3-1

W-3 ____

W-4 ____

W-5 ____

W-6 ____

W-7 ____

AUDIOVISUAL(S)

A-1 ____

A-2 ____

A-3 ____

A-4 ____

A-5 ____

A-6 ____

A-7 ____

LABORATORY ASSIGNMENT(S)

L-1 Assignment SC-3-2

L-2 Assignment SC-3-3

L-3 ____

L-4 ____

L-5 ____

L-6 ____

L-7 ____

L-8 ____

L-9 ____

CHECKPOINT(S)

C-1 Test (written)

C-2 ____

C-3 ____

C-4 ____

C-5 ____

C-6 ____

C-7 ____

C-8 ____

C-9 ____

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340

ACTIVITY SEQUENCE SHEET

Activity	Flow Chart Number	Description of Activity
Assignment SC-3-1	W-1	Read Lennox Solar Manual, Installation, p. 13-16. Most of this should be familiar to you from study of Unit SB-4. Pay particular attention to Figures 13-17.
Assignment SC-3-2	L-1	Answer questions on Assignment Sheet SC-3-2.
Information Sheet SC-3-1	W-2	Read Information Sheet SC-3-1.
Assignment SC-3-3	L-2	Answer questions on Assignment Sheet SC-3-3.
Test	C-1	Written.

a. List two advantages of spherical storage tanks.

   1)

   2)

b. Spherical tanks are not often used because ____________________

____.

c. The most practical shape for a storage tank is ______________.

d. What must be done to steel tanks to prevent internal corrosion?

e. In considering a plastic tank, what characteristic of the tank must be carefully noted?

f. Because of temperature stresses, concrete tanks require

____

____.

g. The minimum useful storage tank temperature is usually at least _______ °F.

INSTALLING THE STORAGE TANK

Since storage tanks are usually large and unwieldy, their installation should be planned early in the installation process. Although installation of storage tanks below grade is possible, this is not recommended because it makes servicing and maintenance of the tank difficult. If below grade tank installation is required, the tank must be very carefully leak-tested before placement. Special moisture-resistant insulation of at least R-30 around the tank is necessary to avoid freezing. The tank should be installed so that servicing is possible.

If the storage tank is to be installed in the attic, it should first be determined that the attic construction can withstand the weight of the filled storage tank. If not, the construction may need to be reinforced.

In houses with basements, storage tank installation in the basement is a common choice. In solar retrofit, careful consideration must be given to how the storage unit will be moved into the basement. If a large tank cannot be moved into the basement, several smaller tanks may be used. In new construction, this problem can be avoided by placing the storage unit after the basement has been built, but before any floor construction has begun.

In most installations, a structural base for the storage tank must be provided. In basement storage tank installations, a concrete structural base may be devised when concrete footings are poured. Depending on its weight, the tank may require a thicker concrete base than the 4-inches normally poured for concrete floors.

Placement of the tank on the structural base should allow for insulation of the bottom of the tank. One way of doing this involves constructing a base of concrete blocks on which are laid 2 x 6" boards. A layer of rigid fiberglass insulation is laid on top of the boards. The tank rests on the insulation. This procedure insulates the tank bottom, and also allows for ventilation of the insulation (see Figure 1).

Before the tank is actually placed on the base, it should be carefully inspected for existing damage. Glass or stone-lined tanks should be especially carefully inspected for cracks or fractures. Galvanized outside coatings should be checked for imperfections. The tank should have appropriate connections for pipes and sensors. Connections on the base of the tank should be made before the tank is placed on the base.

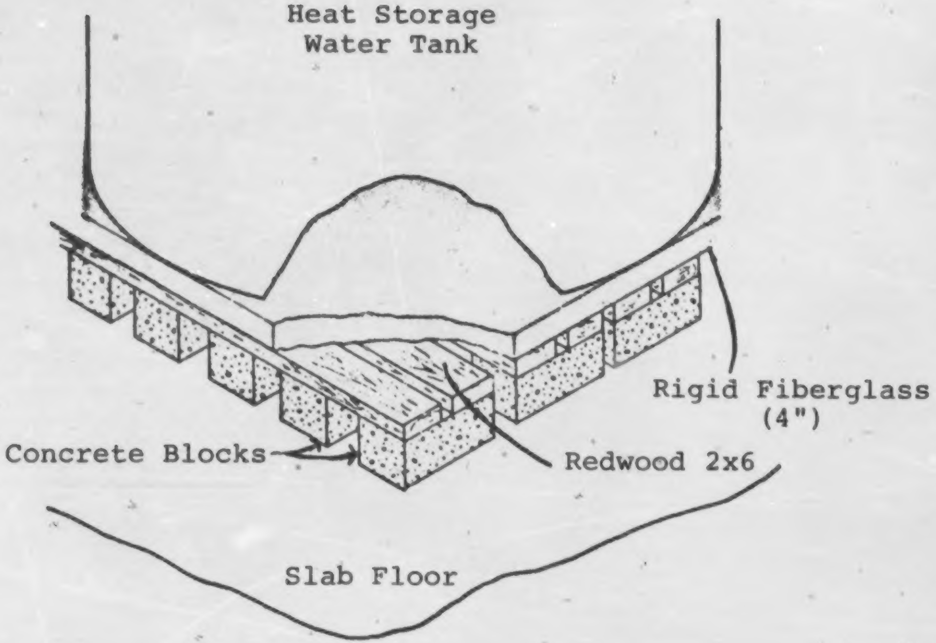


Figure 1. Bottom Insulation and Support Scheme for Water Storage Tanks.

A crane may be used to lift a large, heavy tank into a basement. Once placed on the base, the tank should be leak-tested, before insulation is applied to the tank sides or top. Not only are leaks difficult to detect after being covered with insulation, the heat loss through wet insulation is so large that it is equivalent to no insulation. Standard plumbing precautions should be exercised by placing shut-off valves at strategic locations to isolate the tank. Drain connections should be provided with a valve and hose connection. Neoprene (high temperature) rubber hose connection between the tank and piping is advised to prevent strain at the tank connection and to protect against corrosion where dissimilar metals are used. A bulk head fitting, as illustrated in Figure 2, is an alternative way of providing connections to the tank.

To prevent heat loss, the storage tank must be completely insulated. Insulation of the sides and top should be installed after leak-testing, so that insulation will not need to be removed

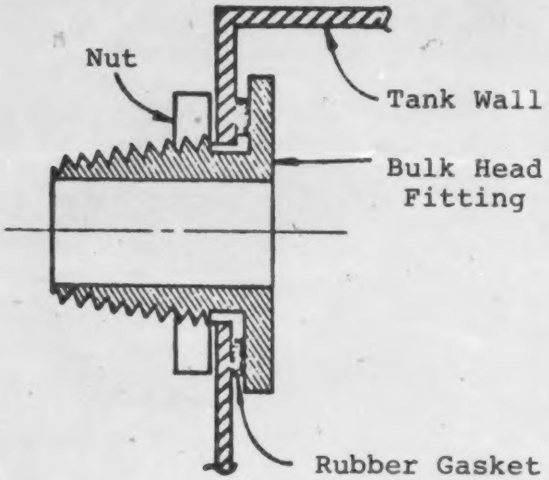


Figure 2. Bulk Head Type Connection.

and replaced if a leak is discovered. Insulation of the tank sides and top can be accomplished by wrapping the tank in conventional fiberglass wool insulation, or by using a spray foam insulation. For tanks placed outside, insulation of at least R-30 is recommended. Insulation of at least R-23 should be used for tanks placed inside. The insulation should be durable for the conditions in which the tank is located. It is especially important that insulation be moisture resistant.

Summary of Steps in Liquid Storage Tank Installation

1) Construct structural base which will withstand the weight of the tank, and which will allow for tank bottom insulation and ventilation.

2) Check tank condition.

3) Place tank on base and insulate bottom.

4) Leak-test tank and connect pipes.

5) Insulate sides and top of tank.

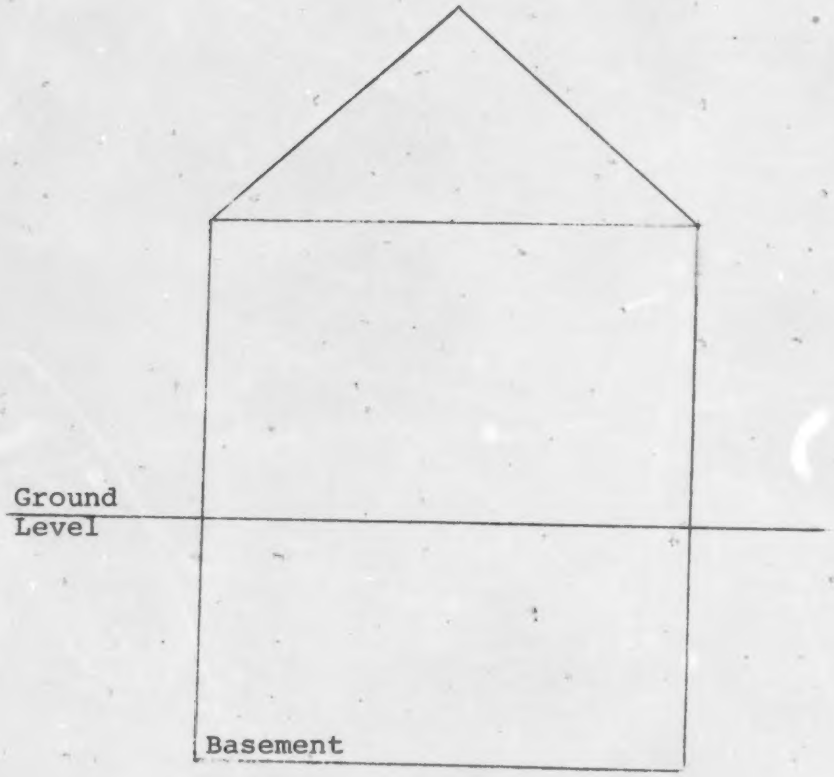
These steps may, of course, be interwoven with other stages of system installation. For example, piping the storage tank to the collectors and load is often delayed until the collectors have been installed. However, if shut-off valves have been installed in the piping leading to and from the storage tank, the tank can be leak-tested by closing these valves and filling the tank.

1) In the drawing below, indicate how you might install a storage tank in a concrete floored basement. Indicate the following:

storage tank (its recommended shape)

storage tank base (its recommended construction)

insulation (recommended R-value)



2) Answer the questions below:

a. What must be checked before a storage tank is installed in the attic?

b. What determines the thickness of structural base that is necessary in a basement storage tank installation?

c. Insulation of at least R-_______ is recommended for tanks placed outdoors. Insulation of R-_______ is recommended for inside tanks.

d. Why is below grade storage tank installation not recommended?

e. Insulation of the storage tank is completed (before, after) leak-testing.

f. To prevent strain at tank-pipe connections, the connection can be made with a __________ __________ __________ or a __________ __________ __________.

g. What is the function of shut-off valves installed in storage tank piping?

h. List the steps in liquid storage tank installation:

1)

2)

3)

4)

5)

SOLAR HEATING SYSTEMS CURRICULUM
UNIT LISTING

PHASE A: BASIC UNDERSTANDING

Unit	Task
SA-1	Explain the value of solar energy and principles of solar radiation.
SA-2	Describe basic solar system components and their functions.

PHASE B: DESIGN

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SB-9	Perform a solar system economic analysis.
SB-10	Recommend a domestic hot water system.

PHASE C: INSTALLATION

Unit	Task
SC-1	Recommend correct thermal mass for direct gain system; fabricate and install modular wall units for passive solar.
SC-2	Schedule solar installation.
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SC-4	Site and mount collectors.
SC-5	Install liquid collectors and outside plumbing.
SC-6	Install inside plumbing for collector load side loops.
SC-7	Install controls and wiring.
SC-8	Start up system.

PHASE D MAINTENANCE

Unit	Task
SD-1	Maintain the solar system.
SD-2	Troubleshoot solar system problems

MAJOR BLOCK Solar Systems (Phase C: Installation) **NAME**

TASK Site and Mount Collectors

UNIT SC-4 **TIME** (est.) (act.)

OBJECTIVE(S) The student will be able to:

1. Choose the most appropriate location for a solar collector array for a specific building orientation and land space availability.
2. Determine the requirements for roof mounting or ground mounting of the solar collector array.
3. Install roof-mounting supports for both accessible and inaccessible rafter conditions.

START → W-1 → L-1 → W-2 → L-2 → W-3 → L-3 → C-1 → W-4 → L-4 → C-2 → L-5 → C-3 → C-4

WRITTEN ASSIGNMENT(S)

W-1 Information Sheet SC-4-1
W-2 Information Sheet SC-4-2
W-3 Information Sheet SC-4-3
W-4 Information Sheet SC-4-4
W-5
W-6
W-7

AUDIOVISUAL(S)

A-1
A-2
A-3
A-4
A-5
A-6
A-7

LABORATORY ASSIGNMENT(S)

L-1 Assignment SC-4-1
L-2 Assignment SC-4-2
L-3 Assignment SC-4-3
L-4 Job Sheet SC-4-1
L-5 Job Sheet SC-4-2
L-6
L-7
L-8
L-9

CHECKPOINT(S)

C-1 Progress Check (peer quiz)
C-2 Observation
C-3 Observation
C-4 Test (written)
C-5
C-6
C-7
C-8
C-9

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ACTIVITY SEQUENCE SHEET

Activity	Flow Chart Number	Description of Activity
Information Sheet SC-4-1	W-1	Read Information Sheet SC-4-1.
Assignment SC-4-1	L-1	Answer questions on Assignment Sheet SC-4-1.
Information Sheet SC-4-2	W-2	Read Information Sheet SC-4-2.
Assignment SC-4-2	L-2	Answer questions on Assignment Sheet SC-4-2.
Information Sheet SC-4-3	W-3	Read Information Sheet SC-4-3.
Assignment SC-4-3	L-3	Answer questions on Assignment Sheet SC-4-3.
Progress check	C-1	Peer quiz.
Information Sheet SC-4-4	W-4	Read Information Sheet SC-4-4.
Job Sheet SC-4-1	L-4	Do activity described on Job Sheet SC-4-1.
Observation	C-2	Observation by teacher of outcome of Job Sheet SC-4-1.
Job Sheet SC-4-2	L-5	Do activity described on Job Sheet SC-4-2.
Observation	C-3	Observation by teacher of outcome of Job Sheet SC-4-2.
Test	C-4	Written.

SITING SOLAR COLLECTORS

A variety of factors must be considered in choosing a site for solar collectors. A basic principle to be followed is to choose a site which allows the collector array to receive as much insolation as is possible. Previous discussion has focused on the importance of tilt angle and collector orientation in determining the amount of insolation received. The appropriate tilt angle will depend on the function of the solar system and on the local latitude. The recommended tilt angles are:

for solar space heating only: latitude + 15°

for solar domestic hot water heating only: latitude

for solar space and hot water heating: latitude

With regard to collector orientation, the collectors should be oriented to face true South. It is important to note that, in most areas, the direction of true South is different from the directionof magnetic South, as determined by a compass. U. S. Geological Survey maps show the relationship between true South and magnetic South. Fortunately, in the state of Georgia, true South and magnetic South are within two degrees of one another for most locations in the State. To estimate true South at a location in Georgia, use a Geological Survey Map to determine the difference between true South and magnetic South at that location, and adjust the magnetic South line, as determined by compass, to reflect this difference. For example, near Savannah, true South is two degrees east of magnetic South. To orient collectors in Savannah, a compass can be used to determine magnetic South, and then the collectors can be oriented two degrees east of the magnetic South line. It is important to note that this method for estimating true South works well only in locations where true and magnetic South are similar.

In addition to choosing an appropriate tilt angle and collector orientation, a variety of other factors must be considered in siting collectors. The collectors should be sited so that they receive a minimum of eight hours of sunlight centered around solar noon. The location of trees, buildings or other surrounding features which might shade the collector array must be considered. A site should be chosen which is free from shade during the critical daylight hours. Where possible, a legal agreement known as a "solar easement" should be obtained to protect the solar homeowner's right of access to sunlight.

Other factors to be considered in siting a collector array include:

- the weight and size of the array, and the appropriateness of proposed sites to support these. It is important to note that not all building roofs are designed to support the weight of a collector array.

- local building codes or other restrictive regulations limiting array location
- the aesthetic impact of mounting a collector array at a specific site, particularly with reference to the architectural design of the building, and with respect to effects on the appearance of the neighborhood.
- the accessibility of the site for necessary system maintenance and repair
- the ease with which other system components may be located and installed relative to the collector array
- the relative advantages of roof versus ground mounting. This topic will be discussed further in upcoming activities.

SITING SOLAR COLLECTORS

1) For each question circle true (T) or false (F).

a. T F Solar collectors should be oriented to directly face magnetic South.

b. T F In all locations, true South and magnetic South are within two degrees of one another.

c. T F In Georgia, true South may be estimated by first determining magnetic South.

d. T F All building roofs are constructed to be able to support collector arrays.

e. T F Local building codes sometimes restrict collector array sites.

f. T F The collector array can be sited without consideration of where other system components will be located.

2) Fill in the blanks with the correct answer:

a. The relation between true South and magnetic South can be seen in a map published by the ______________ ______________ ______________.

b. Trees and building near a prospective collector site must be considered in choosing a site because ____________________ ____.

c. Five factors which must be considered in siting collectors are:

d. Solar collectors must be oriented to face _______________ _______________.

e. A collector array should be sited to receive sunlight for _________ hours a day, centered around _______________ _______________.

f. A legal agreement which guarantees the solar homeowner's right of access to sunlight is called a _______________ _______________.

g. The appropriate tilt angle for a solar space-heating system is ____________________________.

h. Two factors critical to choosing the appropriate collector tilt angle are: ___________________ and ___________________.

ROOF MOUNTING OF COLLECTORS

There are three basic considerations which must be kept in mind when mounting collectors on the roof. First of all, it must be determined that the roof construction has adequate load-bearing capability to accept the weight of the collector array and its associated hardware. This is especially important in retrofit systems, where the roof was not originally designed to support a collector array. Building structural requirements can be found in local building codes. In the absence of local building codes, the Southern Building Code can be consulted. Under no circumstances should a collector array be installed without compliance with applicable minimum structural requirements. If the roof cannot be reinforced to bear the weight of the collector array, the collectors must be mounted on the ground.

A second consideration in installing collectors on the roof is to insure that the roof remains leak-proof despite roof penetrations necessary for installation. Great care and skill must be applied to prevent leaks due to collector installation for the life of the roof. In general, leak-proofing is accomplished through the application of silicone sealant or roofing cement around hardware which penetrates the roof, and through the use of sheet metal flashing.

Finally, the roof installation must provide for resistance to wind, snow, ice and other severe weather conditions. Where the collectors are mounted on frames or racks above the roof, special care must be taken to design the frame so that the array will not be blown off the roof in high winds. The array should be designed to withstand the weight of snow or ice loads. In areas where hail or ice are common winter conditions, collector cover plates should be checked for their resistance to damage by those conditions.

Two basic conditions of roof mounting will be considered:

1) collector mounting for a roof having a suitable tilt angle and orientation

2) collector mounting for a roof with an inappropriate tilt angle and orientation

Condition 1

Collector mounting is simplest if the tilt angle and orientation of the roof are appropriate to the solar system. In Georgia, for solar space-hot water heating systems, a south-facing roof with a tilt angle of about 33° is appropriate. In new construction, collectors may be mounted before shingles are laid. The collectors are mounted immediately after the roof felt is applied to the sheathing. In retrofit systems, the collectors are sometimes mounted directly on top of the shingles. If this is done, special precautions must be taken to avoid water leakage into the area between the collectors and roof, which might cause the roof to rot. Since the collectors reach relatively high temperatures, the kindling point of the roof and shingles should be checked. To avoid the possibilities of roof rot or fire, many installers mount the collectors on stand-offs even when roof angle is suitable. The use of stand-offs will be discussed in the next section.

Where collectors are mounted on roof felt or directly on shingles, mounting blocks or sleepers of rot-resistant wood are first attached to the roof. Woods such as redwood, cedar, or pine which have been treated with a pressure preservative process are acceptable. Silicone sealant or roofing cement is spread liberally underneath the mounting block to insure that the roof penetration attaching the block to the roof is thoroughly sealed. In addition, the mounting blocks or sleepers are flashed with sheet metal. Flashing should include side and end flashing with counter flashing over the top of the block or sleeper. Finally, all mounting belts, lag screws or other hardware which penetrate the roof or the flashing should be liberally covered with roofing cement.

A cross section of a flashed mounting block is shown in Figure 1. Study this drawing and be certain you understand the relationships between the roof and the collector mounting.

Condition 2

In many retrofit solar systems, either the tilt angle or orientation of the existing roof will be inappropriate. In these cases, collectors are mounted on racks or stand-offs which are designed to adjust the tilt angle or orientation. Figure 2 illustrates a stand-off mounting. Stand-off mountings are used to make small adjustments in tilt angle, or to avoid problems of leakage and rotting that may occur if collectors are mounted on the roof.

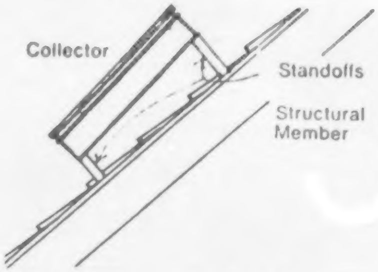


Figure 2. Stand Off Mounting.

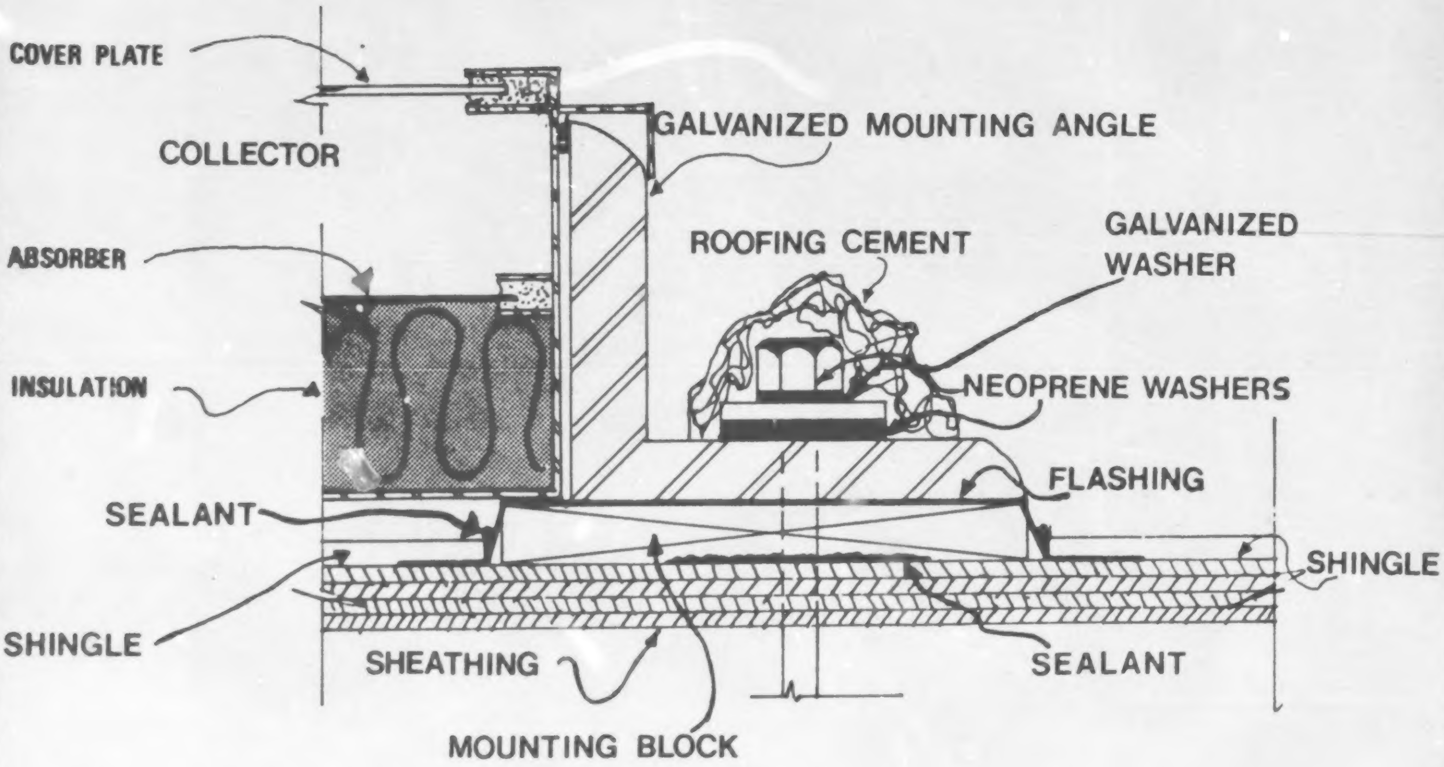

COVER PLATE
COLLECTOR
GALVANIZED MOUNTING ANGLE
ROOFING CEMENT
GALVANIZED WASHER
ABSORBER
INSULATION
NEOPRENE WASHERS
FLASHING
SEALANT
SHINGLE
SHINGLE
SHEATHING
SEALANT
MOUNTING BLOCK

Figure 1. ROOF MOUNTING DETAIL WITH FLASHED MOUNTING BLOCK

Figure 3 shows the detail of a stand-off mounting.

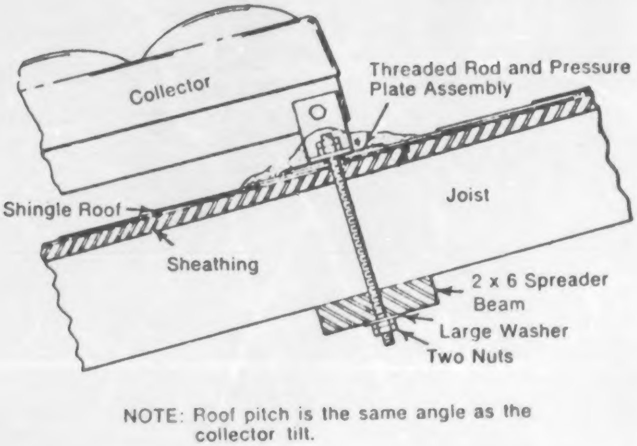

Collector
Threaded Rod and Pressure Plate Assembly
Joist
Shingle Roof
Sheathing
2 x 6 Spreader Beam
Large Washer
Two Nuts
NOTE: Roof pitch is the same angle as the collector tilt.

Figure 3. Detail of Stand-Off Mounting.

Rack mounting (See Figure 4) is used to make major adjustments in tilt angle. The racks are attached to sleepers which are fastened directly to the roof as was described in Condition 1.

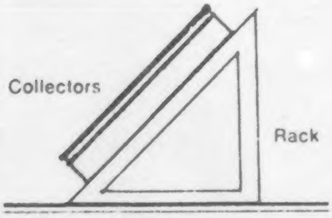

Collectors
Rack

Figure 4. Roof Rack Mounting.

Flat roofs require that the mounting racks be supported by the roof though "pitch pot" mounts, complete with flashing. Examples of the details of pitch pot flat roof mountings are seen in Figure 5.

It is important to note that collectors mounted above the roof, either on stand-offs or racks, are especially vulnerable to wind pressure. Racks and stands should include reinforcing wind bracers (See Figure 6) and should be periodically checked for wind resistance.

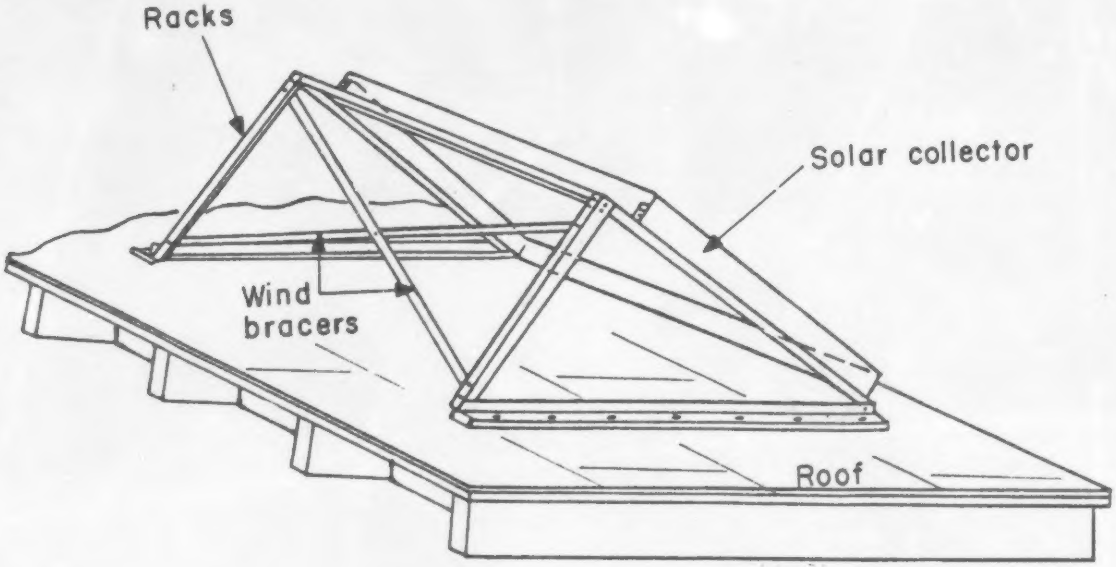


Figure 6. Wind Bracing of Roof Rack.

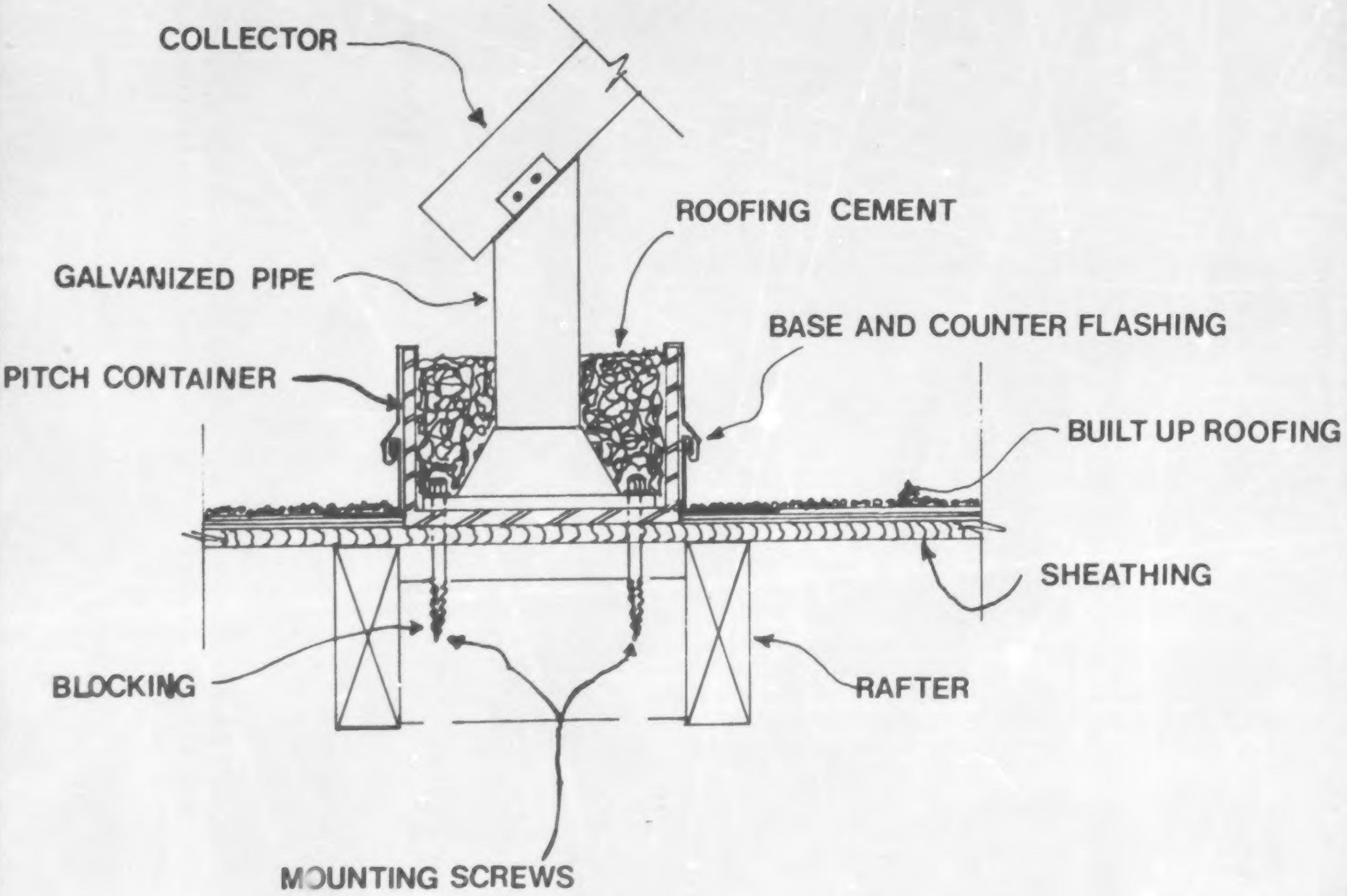

COLLECTOR
ROOFING CEMENT
GALVANIZED PIPE
BASE AND COUNTER FLASHING
PITCH CONTAINER
BUILT UP ROOFING
SHEATHING
BLOCKING
RAFTER
MOUNTING SCREWS

Figure 5. **PITCH POT FLAT ROOF MOUNTING**

ASSIGNMENT SHEET SC-4-2

ROOF MOUNTING OF COLLECTORS

1. Fill in the blanks with the correct answers:

   a. Three basic considerations to be kept in mind when mounting collectors on the roof are:

   b. Building structural requirements for your area can be found in ______________ ______________ ______________.

   c. Rack mounted collector installations must be designed to be particularly resistant to weather conditions of ______________ ______________.

   d. Collectors must be mounted on racks when ______________ ____.

   e. Two procedures used to prevent roof leakage are use of ______________ ______________ and ______________.

   f. In new construction, if roof tilt angle is suitable, the collectors may be mounted on an incomplete roof after ______________ ______________ has been laid.

   g. Pitch pot mounts are used with ______________ roofs.

   h. Two types of washers which are used on the bolt or lag screw which holds the collector mounting brackets to the roof are ______________ and ______________ washers.

   i. Two possible problems if collectors are mounted directly on top on roof shingles are ______________ and ______________ ______________.

   j. If roof angle is suitable, but it is not desired to mount the collectors directly on the roof, the collectors are mounted on ____________________.

   k. If major adjustments in roof tilt angle must be made, collectors are mounted on ______________.

2. Draw a cross-section of a collector mounting directly on top of an existing roof. Indicate the following:

   a. location of sheathing and shingles
   b. location of mounting block
   c. where sealant is applied
   d. where flashing is applied
   e. how the collector fits into the mount

COLLECTOR GROUND MOUNTING

Collector ground mounting involves many of the considerations discussed in siting collectors (See Information Sheet SC-4-1). There are also a variety of special considerations. Ground mounted collectors are more accessible to people, and therefore pose a potential safety hazard. The collectors reach high temperatures, as does the connective piping, which must be well insulated. To insure safety, and also to minimize vandalism, it is sometimes desirable to fence in the collector array. A wire mesh net may be installed above the array to protect it from falling objects. However, it is important that the array be accessible for maintenance and repair. Manufacturers' specifications can be consulted to determine accessibility requirements so that protective measures can be properly designed.

Ground mounting often requires that penetrations be made at lower levels of the building. Such penetrations must be thoroughly sealed against moisture, and against the entry into the building of rodents, insects, or other unwanted creatures.

Supports used in ground mounting should be established in the ground below the frost line. The depth requirement for this can be obtained from local building codes or the Southern Building Code. Concrete footings should be used to support the collectors, and these should include a minimum of ½-inch diameter threaded rod anchors to attach the collectors to the footings. Any wood used in ground mounting must be treated to resist termites and rot.

The bottom edge of the collectors should be a minimum of two feet above the ground so that the collectors are not easily covered with dirt splashed by rainfall or water running off the collectors. If the collector being installed has weep holes on the lower edge, these should be plugged with fiberglass rope to prevent entry by insects. These holes should not be sealed tight since the collector must "breathe" with temperature changes and allow escape of condensed moisture.

The ground mounting of collectors is illustrated in Figure 1.

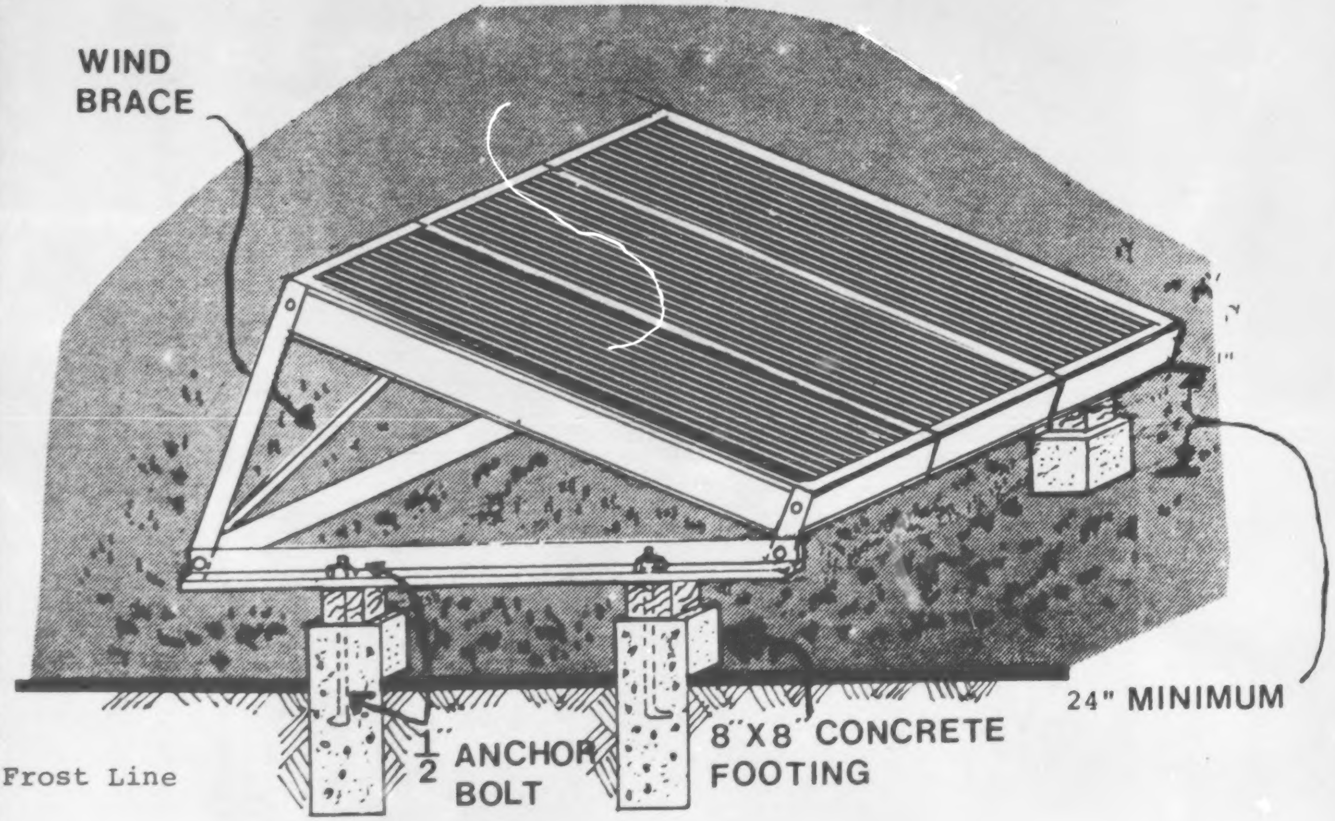

WIND BRACE
1"
24" MINIMUM
1/2" ANCHOR BOLT
8"X8" CONCRETE FOOTING
Frost Line

Figure 1. **GROUND MOUNTED COLLECTORS**

ASSIGNMENT SHEET SC-4-3

GROUND MOUNTING OF COLLECTORS

1. List preventive measures for avoiding the problems below associated with ground mounting of collectors:

Possible Problem	Preventive Measure
1. People being burned by collector or piping.	1.
2. Vandalism.	2.
3. Damage to collectors by falling objects.	3.
4. Entry of insects into house through system wall penetrations.	4.

2. Identify each statement as true (T) or false (F).

a. T F Ground mounting supports should be established above the frost line.

b. T F Footings should include a minimum of ½-inch diameter threaded rod anchor.

c. T F The collector bottom edge should be two feet above the ground.

d. T F Collector weep holes should be sealed tight when collectors are ground mounted.

e. T F Wood footings are often used for ground mounting.

FASTENING MOUNTING BLOCKS OR SLEEPERS TO THE ROOF

There are two methods used to fasten mounting blocks or sleepers to the roof. These are:

1) spanner mounting
2) lag screw mounting.

Spanner Mounting

Spanner mounting requires access to the attic space of the building or to the underneath roof structure. Figure 1 illustrates a spanner mounting. The first step in spanner mounting is to locate the point at which the mounting bolts will pass through the roof. The mounting bolts are installed at a point in the roof exactly between two rafters or joists. (See Figure 2). The rafters can be located by tapping the top of the roof. Solid sounding points indicate rafters. The mounting bolt hole is drilled at a point centered between the rafters or joists. A ½-inch diameter bolt (minimum size) is passed through the roof between the rafters, and through a "spanner block" which spans across the rafters or joists on the roof interior. The spanner block distributes the weight of the collectors across the rafters. Finally, on each side of the bolt, spacer blocks are installed to minimize point loading and to prevent deflection of the spanner block when the assembly is tightened. The spacer blocks should be installed so that the assembly is tight against both rafters and the spacer blocks. This may require that the spacer blocks be planed to a depth about 1/8" less than that of the rafters or joists.

Lag Screw Mounting

Lag screw mounting is used mainly when the underneath roof structure is not accessible for installation of the spanner beam assembly. A lag screw mounting is shown in Figure 3. In the lag screw mounting, holes are drilled through the roofing and sheathing and into the rafters (or joists) so that lag screws can be installed through the mounting blocks or sleepers into the rafters. The lag screws must be installed such that the penetration is a minimum depth of 2 inches into the rafters. The lag screws must be ½-inch or larger in size and the holes drilled into the rafters must be the correct size for the lag screws used. See the manufacturers instructions for this information, or if no information is available, use a drill size at least 1/8-inch smaller than the lag screw size. The holes through the mounting blocks or sleepers and through the roof sheathing must be drilled 1/16 inch larger in diameter than the lag screw so that the mounting is not split and the sheathing is not distorted.

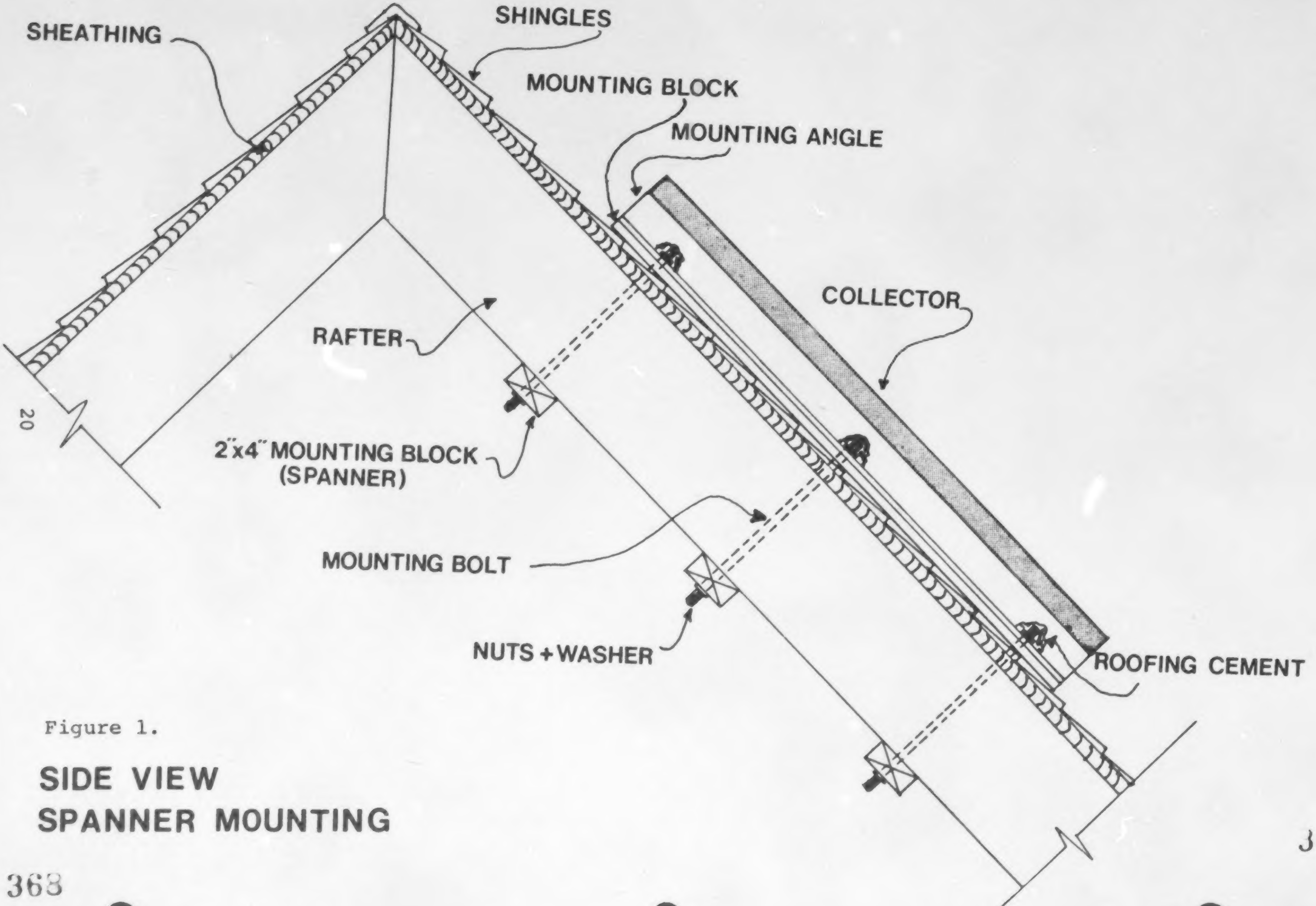

SHEATHING
SHINGLES
MOUNTING BLOCK
MOUNTING ANGLE
COLLECTOR
RAFTER
2"x4" MOUNTING BLOCK (SPANNER)
MOUNTING BOLT
NUTS + WASHER
ROOFING CEMENT

Figure 1.

SIDE VIEW
SPANNER MOUNTING

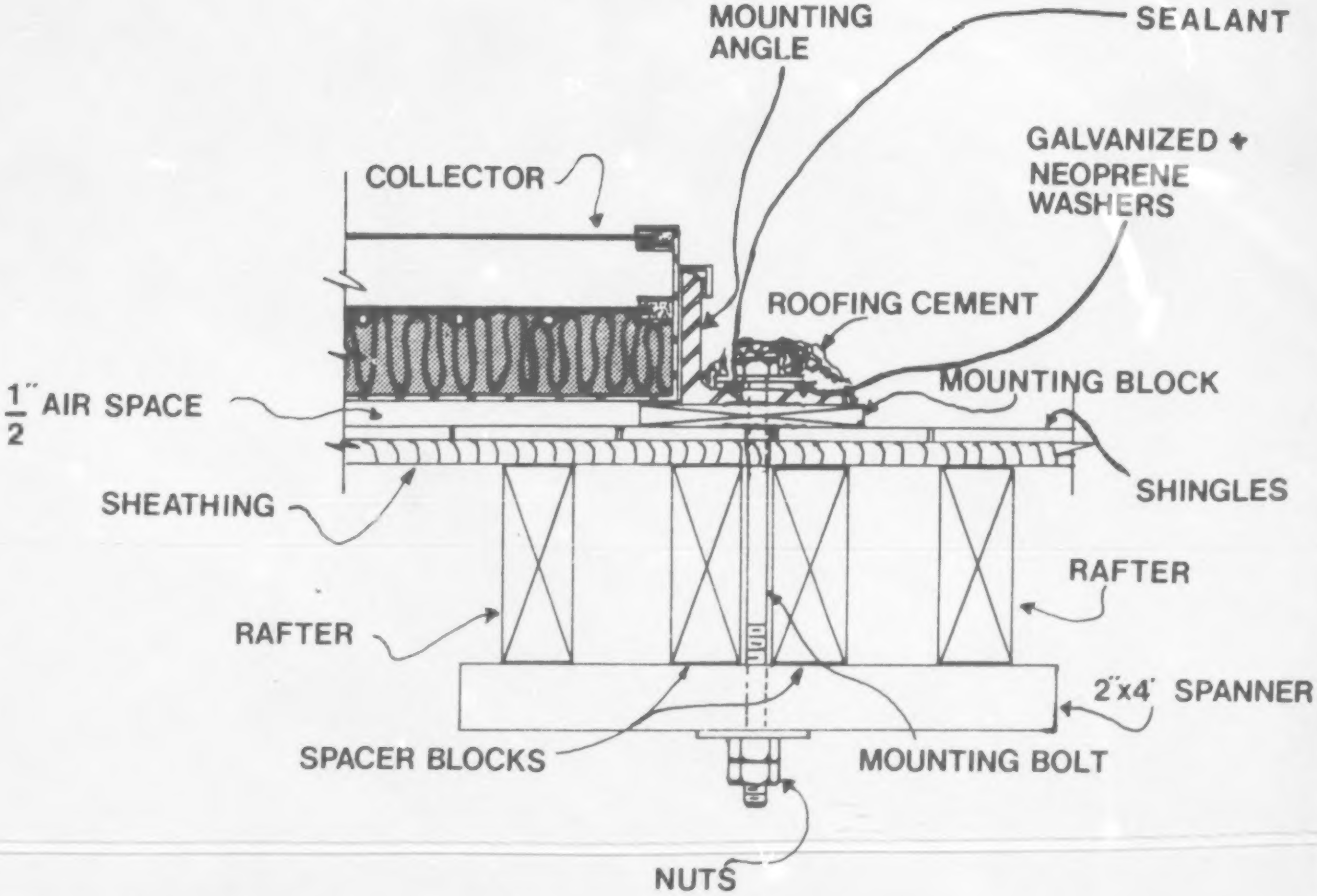

MOUNTING ANGLE
SEALANT
GALVANIZED + NEOPRENE WASHERS
COLLECTOR
ROOFING CEMENT
MOUNTING BLOCK
$\frac{1}{2}$" AIR SPACE
SHINGLES
SHEATHING
RAFTER
RAFTER
2"x4" SPANNER
SPACER BLOCKS
MOUNTING BOLT
NUTS

Figure 2. SPANNER MOUNTING DETAIL

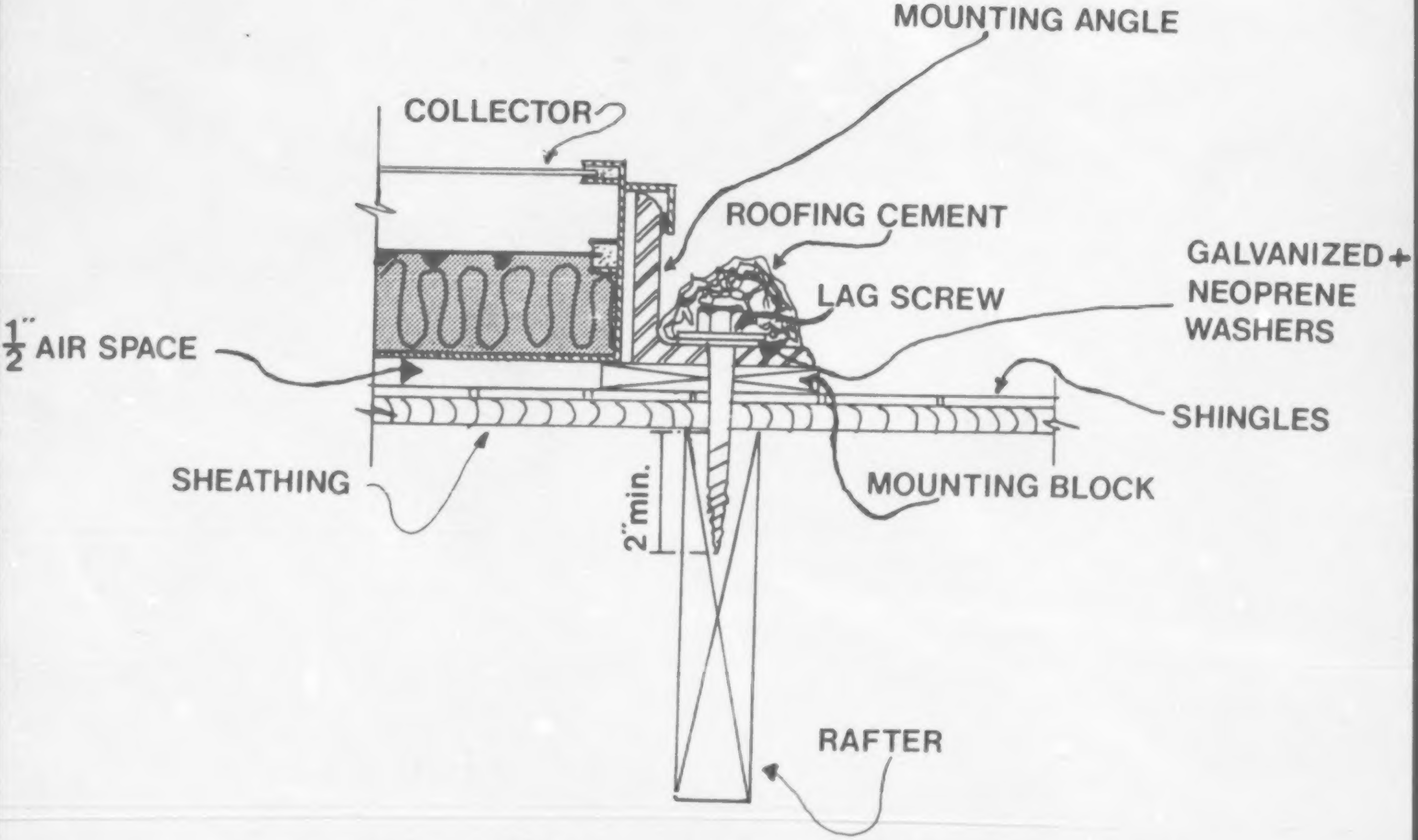

MOUNTING ANGLE
COLLECTOR
ROOFING CEMENT
GALVANIZED +
NEOPRENE
WASHERS
LAG SCREW
½" AIR SPACE
SHINGLES
SHEATHING
2" min.
MOUNTING BLOCK
RAFTER

Figure 3. **LAG SCREW MOUNTING DETAIL**

A lag screw mounting arrangement or a flat roof is shown in Figure 4. In this case, the lag screw mounting occurs where the underneath roof is accessible. Anchor blocking has been installed to accept the lag screws. Note that the anchor blocking has been nailed securely to the rafters to provide for load transfer. Lag screws should never be installed directly into the sheathing alone with no blocking to transfer loads into the rafters.

Remember: In all cases where roof penetrations are made, silicone sealants, roofing cement and flashing must be used to prevent roof leakage.

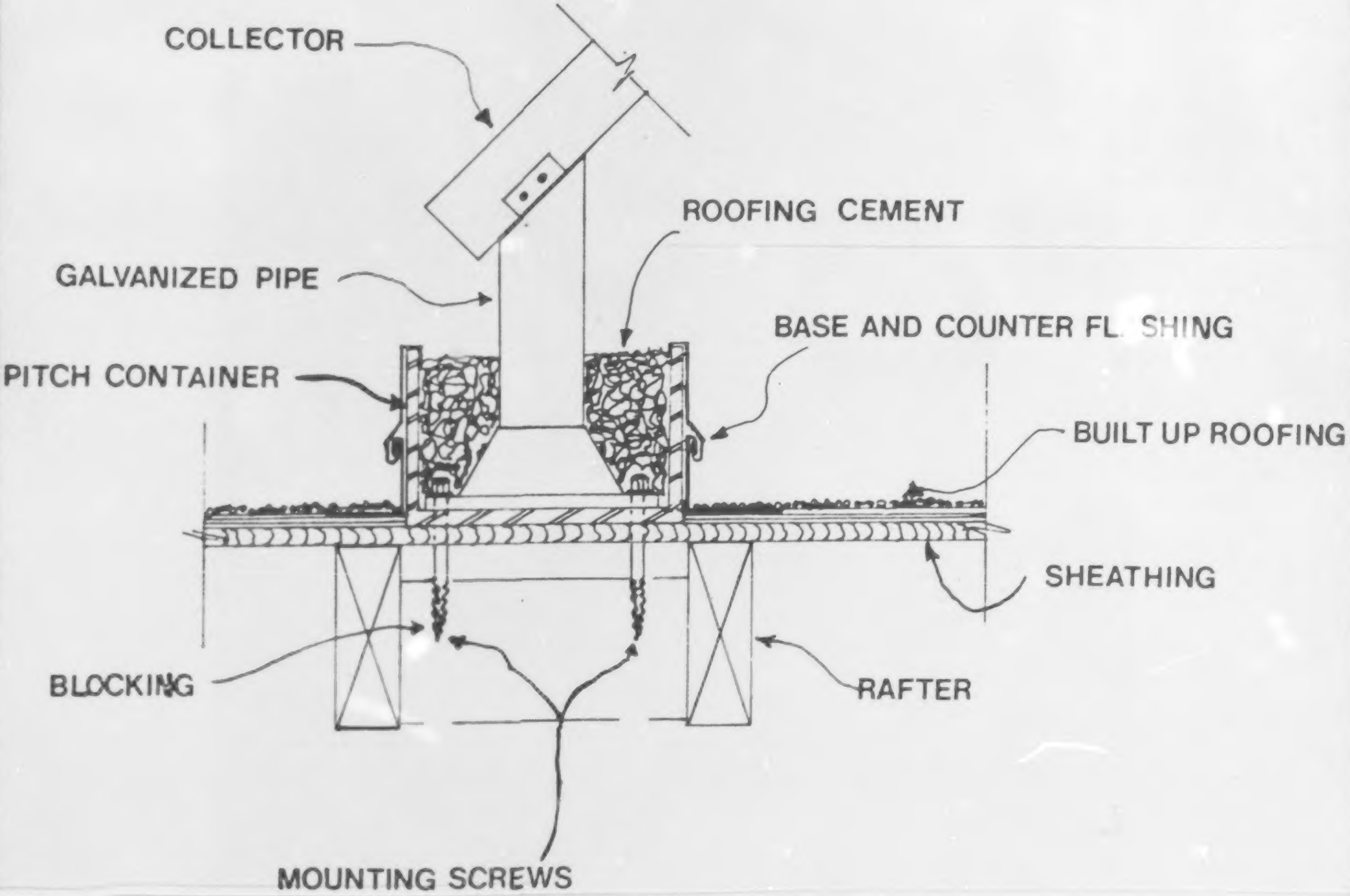

COLLECTOR
ROOFING CEMENT
GALVANIZED PIPE
BASE AND COUNTER FLASHING
PITCH CONTAINER
BUILT UP ROOFING
SHEATHING
BLOCKING
RAFTER
MOUNTING SCREWS

Figure 4. PITCH POT FLAT ROOF MOUNTING

JOB SHEET SC-4-1

SPANNER MOUNTING

Objective: To prepare and install a typical spanner mounting assembly.

Materials and Equipment:

(1) One (1) sheet of 5/8-inch thick plywood roof sheathing, 24 inches square.

(2) Three (3) pieces of 2" x 8" No. 3 Utility Fir (or No. 2 Yellow Pine), 24 inches long.

(3) One (1) piece of 2" x 4" No. 2 Yellow Pine (or equivalent), 24 inches long.

(4) One (1) piece of 1" x 6" No. 2, Pressure Treated Yellow Pine, 6 inches long.

(5) One (1) piece 15-pound roofing felt, 24 inches by 24 inches square.

(6) One (1) piece roll roofing, 24 inches by 24 inches square.

(7) Eight (8) 16d cc Sinkers (Nails).

(8) One (1) tube asphalt roofing cement (11 oz) and caulking-gun (or bulk roofing cement) and a 2-inch putty knife.

(9) One quart of mineral spirits.

(10) One (1), ½-inch diameter hex head galvanized bolt, 12 inches long.

(11) Two (2) galvanized ½-inch hex nuts.

(12) Two (2) galvanized ½-inch flat washers.

(13) One (1) neoprene ½-inch washer.

(14) Two (2) box-end or socket-wrenches sized for the ½-inch bolt head and nut.

(15) One (1) angle, 3" x 3" x 3/32" galvanized slotted angle, 4 inches long (simulates collector "clip" or "mounting angle").

(16) One (1) carpenters hammer.

(17) Twenty-four (24), 7/8-inch long galvanized roofing nails.

(18) One (1) steel tape.

(19) One (1) hand saw.

(20) One (1) 9/16-inch diameter drill-bit and drill motor.

(21) One (1) carpenter's square.

(22) One (1) carpenter's pencil.

(23) One (1) 3" x 21" belt Sander with a coarse belt.

(24) One (1) expandable clean-up rag (or paper towels).

Procedure:

1. Lay-out on the unfinished side of the 24-inch square of 5/8 inch plywood two lines on a 16-inch spacing and centered on the baord. Figure 1a shows this lay-out.
2. Using the lines prepared in (1), place reference marks on the edges of the plywood sheet corresponding to these lines.
3. Lay two (2) of the 2" x 8" x 24" pieces on-edge on a sturdy table or bench or on the floor and place the plywood over them, centering the edge marks on the plywood on the 1½ board edge as shown in Figure 1b.
4. Nail the plywood to the two (2) 2" x 8" boards using four (4) of the 16d nails for each board. Nail at the ends approximately 2 inches from the edges and then at approximately equal distances along each board. This is shown in Figure 1c.
5. Nail the 15-pound felt to the surface of the plywood using twelve (12) of the 7/8 inch galvanized roofing nails as shown in Figure 1d.
6. Nail the roll-roofing over the felt using the remaining twelve (12) roofing nails as shown in Figure 1e. (This now completes a simulated roof section.)
7. Measure from the edges of the section and locate the center of the unit and mark a line down the center as shown in Figure 1f.

8. Measure along this center line from one edge and mark at six inches as shown in Figure 1f, also.

9. Drill through the roof section at this point with the 9/16 inch diameter drill.

10. Measure and mark the center of one face of the 1" x 6" x 6" treated pine block. Drill through the block at this point using the 9/16 inch diameter drill.

11. Place one of the galvanized flat washers on the ½-inch bolt and then follow this washer with the neoprene washer.

12. Drill the slotted angle with the 9/16 inch drill to "open-up" an existing hole or slot at the mid-point of one flange. NOTE: Extreme care and the use of a metal vise is required for this operation to avoid possible injury!

13. Insert the bolt through the slotted angle flange and then through the 1" x 6" x 6" mounting block. This arrangement is shown in Figure 1g.

14. Apply asphalt cement "liberally" to the surface of the block around the location where the bolt projects through and to the entire surface of the block in a thickness of not less than the equivalent of 1/8-inch.

15. Insert the bolt through the roof section and apply pressure to cause the roofing cement to flow and seal to the roofing surface. This is shown in Figure 1h.

16. Turn the roof section "on-end" with the block and bolt assembly towards the bottom.

17. Cut two pieces of 2" x 8" fir at approximately twelve (12) inches length using the remaining piece of 2" x 8" at 24-inches length. (Note: The lengths of the two pieces will be slightly less than 12-inches due to the saw-cut width.)

18. Stand the two pieces of 2" x 8" x 12" along the inside of the simulated rafters. Check their relative depths and if necessary, sand them to achieve depths of 1/8-inch less than the simulated rafters. This is shown in Figure 1i.

19. Stand the two pieces of 2" x 8" x 12", which have been finished to provide the 1/8-inch less depth, along each side of the ½-inch bolt which projects through the underneath surface of the simulated roof sheathing.

20. Mark off and drill in the face of the 2" x 4" x 24" piece a 9/16" diameter hole. This is the "spanner bar." Slide the spanner bar over the bolt, perpendicular to and up to the rafter lower surfaces, as shown in Figure 1j.

21. Place a ½-inch, galvanized washer over the bolt.

22. Install one of the ½-inch hex nuts on the bolt, and tighten it until the spanner bar deflects and the 2" x 4" spanner bar is securely tightened to the spacer blocks. This is shown in Figure 1k.

23. Place the remaining nut on the bolt and tighten it securely against the first nut while holding the first nut.

24. Ask the Instructor to examine the assembly.

25. After the Instructor has examined and approved the assembly (adjustments may be required,) coat the mounting block and bolt head and washers liberally with roofing cement. Make sure the assembly is sealed.

26. Request a final examination by the Instructor.

27. Clean up all tools using the mineral spirits.

28. Return tools and safety equipment to storage and dispose of waste.

29. Place completed assembly in storage for subsequent use, as required.

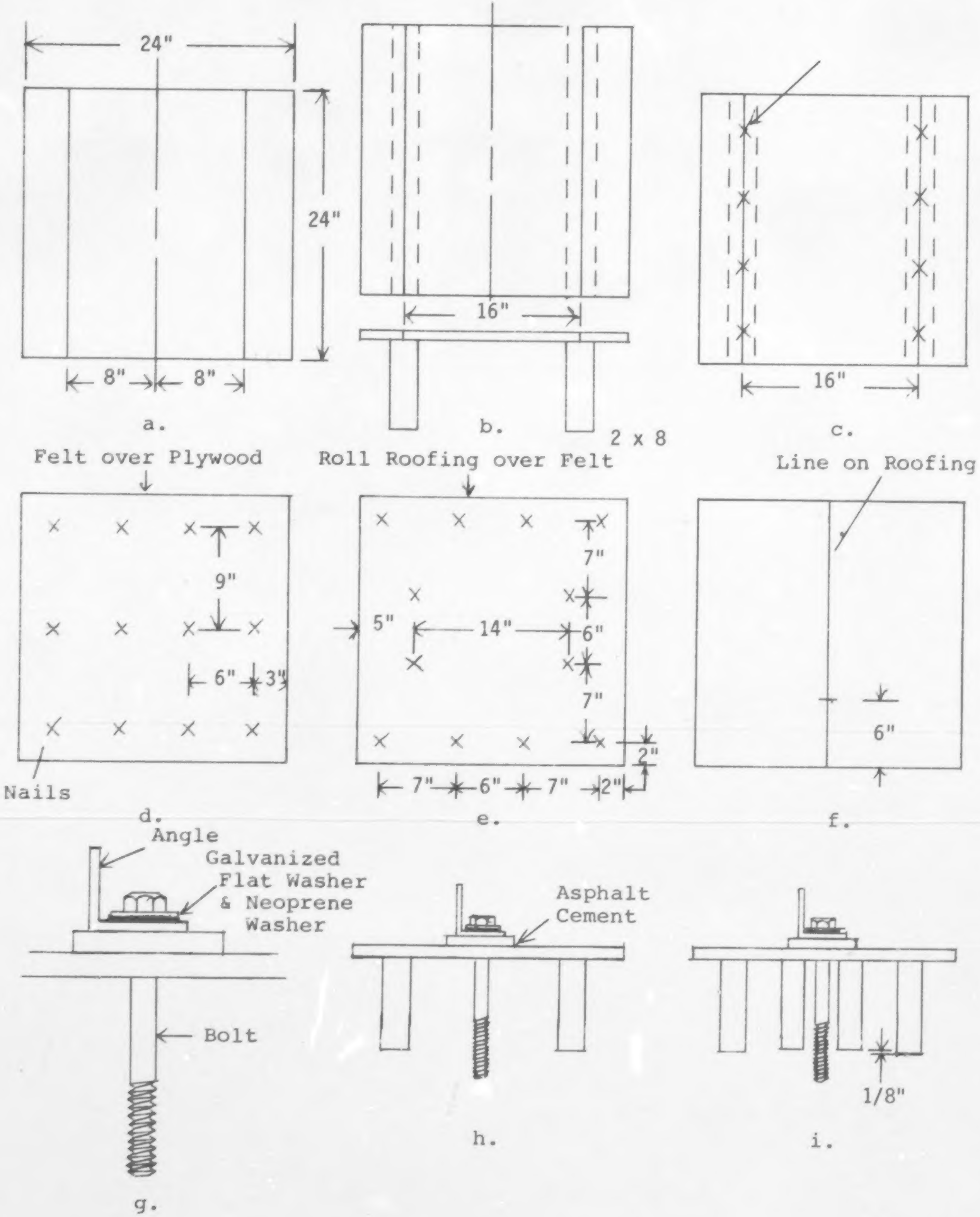
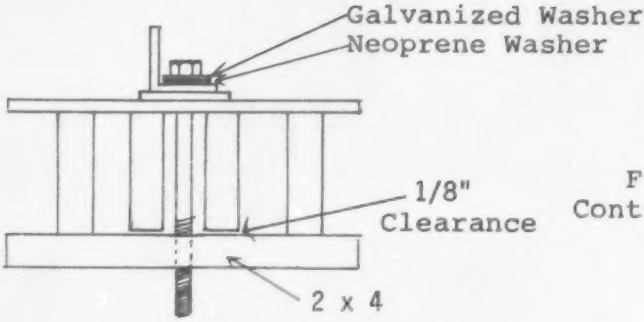
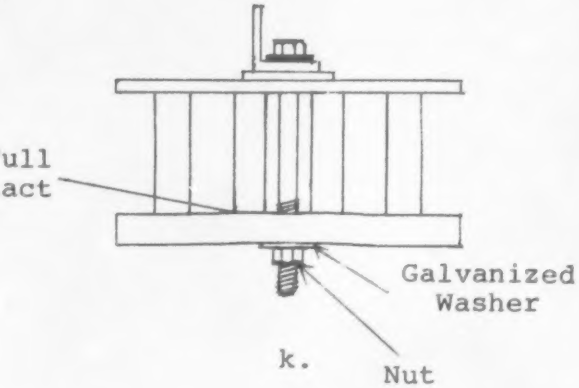

24"
24"
8"
8"
a.
16"
b.
2 x 8
16"
c.
Felt over Plywood
Roll Roofing over Felt
Line on Roofing
9"
6"
3"
Nails
d.
5"
14"
7"
6"
7"
7"
6"
7"
2"
2"
e.
6"
f.
Angle
Galvanized Flat Washer & Neoprene Washer
Bolt
g.
Asphalt Cement
h.
1/8"
i.

Figure 1. Spanner Mounting.


Galvanized Washer
Neoprene Washer
1/8" Clearance
2 x 4

j.


Full Contact
Galvanized Washer
Nut

k.

JOB SHEET SC-4-2

LAB SCREW MOUNTING

Objective: To construct a lag screw mounting assembly.

Materials and Equipment:

(1) The spanner mounting assembly and simulated roof section constructed under Job Sheet SC-4-1.

(2) One (1) piece of 2" x 8", No. 3 Utility Fir (or No. 2 pine), 15-inches long.

(3) Eight (8) 16d cc Sinkers (nails).

(4) One (1) piece of 1" x 6" No. 2 pressure treated yellow pine, 6-inches long.

(5) One (1) piece of galvanized slotted angle, 3" x 3" x 3/32" 4-inches long.

(6) One (1) 9/16-inch diameter drill bit and drill motor.

(7) One (1), ½-inch diameter lag screw, 3-inches long.

(8) One (1), 3/8-inch diameter drill bit.

(9) One (1), carpenter's hammer.

(10) One (1), carpenter's square.

(11) One (1), steel tape.

(12) One (1), hand saw.

(13) One (1), carpenter's pencil.

(14) One (1), ½-inch galvanized flat washer.

(15) One (1), box-end or socket wrench sized for the ½-inch lag screw head.

(16) One (1), tube asphalt roofing cement (11 oz.) and caulking gun (or bulk roofing cement) and a 2-inch putty knife.

(17) One (1) quart mineral spirits.

(18) One (1) galvanized ½-inch washer.

(19) One (1) neoprene ½-inch washer.

(20) One (1) expendable clean-up rag (or paper towels).

Procedure:

1. Stand the simulated roof section with the spanner assembly on edge with the spanner assembly down.

2. Measure from the top end along the edge of each rafter section and mask the edge of the rafter sections at 6-inches. Use the carpenter's square to mark a perpendicular straight line across each rafter edge at this point.

3. Measure between the rafters at the 6-inch point (this dimension should be 14½-inches ± 1/16-inch, if the original assembly is correct).

4. Square end and cut the required length of 2" x 8" from the 15-inch piece.

5. Place the cut section of 2" x 8" between the rafters (perpendicular) and center it at each end on the rafter marks at 6-inches. The assembly should appear as shown in Figure 1a when viewed from the bottom of the roof section.

6. Nail the 2" x 8" support block to the rafter sections using the 16d nails. Use four nails in each end. This is shown in Figure 1b.

7. Turn the roof section so that the roofing is to the top. This will require that spacer blocks be used to hold the section off the table, bench or floor because of the previously installed spanner mount assembly bolt. A slight tilt of the section will result if spacer blocks are used under the spanner bar to clear the bolt projection.

8. Measure and mark the surface of the roofing at a point 6-inches from the edge and at the center between the rafter sections. This should be a location in the direct center of the previously installed 2" x 8" support block. This is shown in Figure 1c.

9. Drill the roofing and sheathing with the 9/16-inch diameter drill only through the sheathing and not into the support bar!

10. Drill the slotted angle with the 9/16-inch drill to "open up" an existing hole or slot at the mid-point of one flange. Note: Extreme care and the use of a metal vise is required for this operation to avoid possible injury.

11. Replace the 9/16-inch drill bit with the 3/8-inch drill bit and drill into the 2" x 8" spacer block for a depth of 2½ to 3-inches.

12. Place one of the galvanized flat washers on the ½-inch lag screw and then follow this washer with the neoprene washer.

13. Insert the lag screw through the slotted angle flange and then through the 1" x 6" x 6" mounting block.

14. Apply asphalt cement "liberally" to the surface of the block around the location where the lag screw projects through and to the entire surface of the block in a thickness of not less than the equivalent of 1/8-inch.

15. Insert the lag screw into the drilled hole and "start" the threads.

16. Press the mounting block to the roofing surface until a good seal is formed and the asphalt cement flows out from under the block.

17. Use the socket wrench or end-wrench and screw the lag screw securely into the roof section support block.

18. Ask the Instructor to examine the assembly.

19. After the Instructor has examined and approved the assembly (adjustments may be required), coat the mounting block, lag screw, and washers liberally with roofing cement. Make sure the assembly is sealed.

20. Request a final examination by the Instructor.

21. Clean-up all tools using the mineral spirits.

22. Return tools and safety equipment to storage and dispose of waste.

23. Place completed assembly in storage for subsequent use, as required.

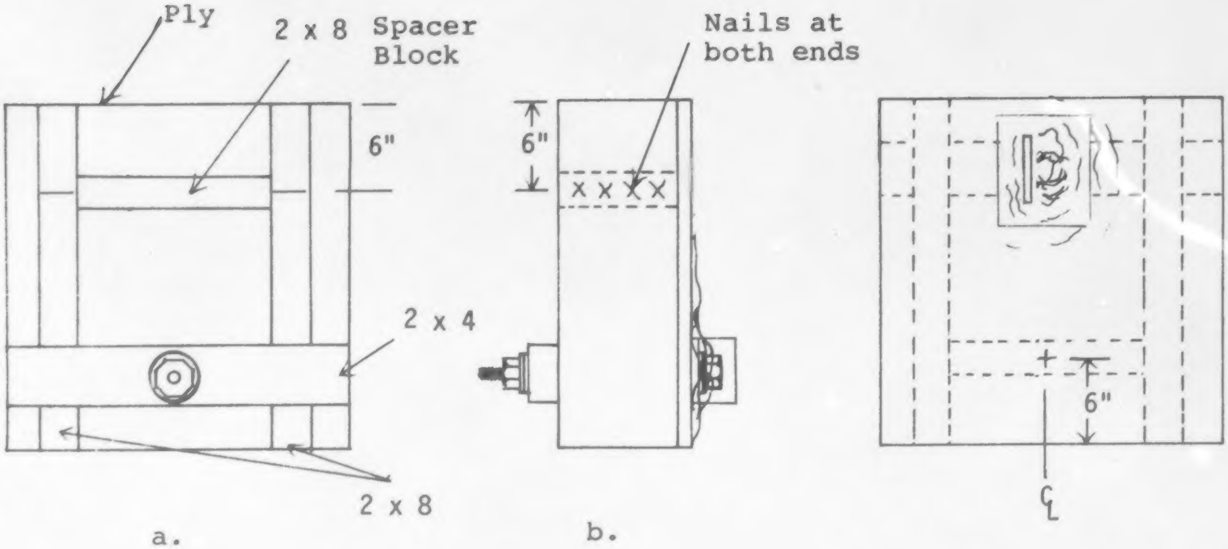

Ply
2 x 8 Spacer Block
6"
2 x 4
2 x 8
a.
Nails at both ends
6"
b.
6"
℄

Figure 1. Lag screw mounting.

SOLAR HEATING SYSTEMS CURRICULUM
UNIT LISTING

PHASE A: BASIC UNDERSTANDING

Unit	Task
SA-1	Explain the value of solar energy and principles of solar radiation.
SA-2	Describe basic solar system components and their functions.

PHASE B: DESIGN

Unit	Task
SB-1	Recommend non-solar energy conservation measures.
SB-2	Select passive solar approaches for new construction.
SB-3	Recommend collectors.
SB-4	Recommend and site the thermal storage unit.
SB-5	Recommend control devices.
SB-6	Recognize and describe modes of solar system operation.
SB-7	Calculate heat load for space or domestic hot water heating.
SB-8	Size solar system components.
SB-9	Perform a solar system economic analysis.
SB-10	Recommend a domestic hot water system.

PHASE C: INSTALLATION

Unit	Task
SC-1	Recommend correct thermal mass for direct gain system; fabricate and install modular wall units for passive solar.
SC-2	Schedule solar installation.
SC-3	Install a liquid storage tank.
SC-4	Site and mount collectors.
SC-5	Install liquid collectors and outside plumbing.
SC-6	Install inside plumbing for collector load side loops.
SC-7	Install controls and wiring.
SC-8	Start up system.

PHASE D MAINTENANCE

Unit	Task
SD-1	Maintain the solar system.
SD-2	Troubleshoot solar system problems

MAJOR BLOCK (Phase C: Solar Systems Installation) **NAME** ____________

TASK Install Liquid Collectors and Outside Plumbing

UNIT SC-5 **TIME** (est.) ________ (act.) ______

OBJECTIVE(S) The student should be able to:

(1) correctly and safely install collectors in the proper location

(2) install outside plumbing loop with the selected design circuit

(3) check plumbing for leaks

(4) make sound roof penetrations for plumbing

START	➔	W-1	W-2	W-3	L-1	W-4	L-2	W-5	L-3
L-4	C-1	W-6	L-5	L-6	C-2	L-7	C-3	C-4	

WRITTEN ASSIGNMENT(S)		**AUDIOVISUAL(S)**	
W-1	Information Sheet SC-5-1	A-1	
W-2	Assignment SC-5-1	A-2	
W-3	Assignment SC-5-2	A-3	
W-4	Assignment SC-5-4	A-4	
W-5	Assignment SC-5-6	A-5	
W-6	Assignment SC-5-8	A-6	
W-7		A-7	

LABORATORY ASSIGNMENT(S)		**CHECKPOINT(S)**	
L-1	Assignment SC-5-3	C-1	Observation
L-2	Assignment SC-5-5	C-2	Observation
L-3	Assignment SC-5-7	C-3	Progress check (written quiz)
L-4	Job Sheet SC-5-1	C-4	Test (written)
L-5	Assignment SC-5-9	C-5	
L-6	Job Sheet SC-5-2	C-6	
L-7	Job Sheet SC-5-3	C-7	
L-8		C-8	
L-9		C-9	

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Superintendent of Schools
1979

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386

ACTIVITY SEQUENCE SHEET

Activity	Flow Chart Number	Description of Activity
Information Sheet SC-5-1	W-1	Read Information Sheet SC-5-1
Assignment SC-5-1	W-2	Read Lennox Solar Manual; Installation, "Installing a Typical Liquid Solar Space Heating/Domestic Hot Water System," p. 21 - 28. Note: Text error. The drawings referred to in the text as being on p. 3-6 are on p. 22-25.
Assignment SC-5-2	W-3	Read Fundamentals, p. 9-6. "Collector Array Installation" to "Rough in Plumbing."
Assignment SC-5-3	L-1	Answer study questions on Assignment Sheet SC-5-3.
Assignment SC-5-4	W-4	Read Fundamentals, p. 9-6 to 9-13. "Rough in Plumbing" to "Electrical Service."
Assignment SC-5-5	L-2	Answer study questions on Assignment Sheet SC-5-5.
Assignment SC-5-6	W-5	Read Lennox Solar Manual; Installation, "Installing a Typical Liquid Solar Space Heating/Domestic Hot Water System," p. 29-32; Review "Good Piping Practices," p. 20.
Assignment SC-5-7	L-3	Answer study questions on Assignment Sheet SC-5-7.
Job Sheet SC-5-1	L-4	Do activity described on Job Sheet SC-5-1.
Observation	C-1	Observation by Instructor to outcome solution of Job Sheet SC-5-1.
Assignment SC-5-8	W-6	Read Lennox Solar Manual, "Installing a Typical Liquid Solar Space Heating Domestic Hot Water System," p. 33.
Assignment SC-5-9	L-5	Answer study questions on Assignment Sheet SC-5-9.

Activity	Flow Chart Number	Description of Activity
Job Sheet SC-5-2	L-6	Do activity described on Job Sheet SC-5-2.
Observation	C-2	Observation by Instructor (Instructor Guide).
Job Sheet SC-5-3	L-7	Do activity described on Job Sheet SC-5-3.
Progress Check	C-3	Student will answer questions on Job Sheet SC-5-3 for Instructor (Instructor Guide).
Unit Test	C-4	Written.

INTRODUCTORY COMMENTS

This unit is mainly about the installation of solar collectors, after correct supports have been provided. You will notice that a method of providing collector support is described which is different from the methods covered in Unit SC-4. No one best method for building collector supports has been selected. All the methods described in this course have been used successfully in the field.

A hand method for raising collectors to roofs is described in this unit. Some installers now use a crane to lift preassembled collector arrays to the roof. This method is safer and faster than the hand method.

Since solar technology is new and rapidly changing, it is not possible to include all methods now in use. This course is designed to show you some of the better ones.

Answer the study questions below:

a. An important part in planning the solar installation so that you will know how every component fits together is to ______________________________.

b. Another important step prior to beginning the actual installation so as to prevent costly delays is to ______________________________.

c. In the Lennox installation system, collector supports are attached by nailing directly to the vertical boards attached to the roof. These vertical 2x4 boards are designated as ______________.

d. The vertical 2x4 members are nailed directly to the roof trusses and are covered with sheet metal flashing. What is the purpose of the sheet metal flashing? ______________________________.

e. The members placed horizontally across the vertical members are called supports. What type of wood and what size is recommended for the top support of the top row and the bottom support of the bottom row? ______________________________

f. Although it is not explained in your reading assignment, can you think of a reason why a particular type of wood is specified for the collector supports?

g. What determines the vertical spacing distance of supports?

h. What is the minimum suggested distance between collector rows? ______________

i. Your reading assignment does not explain the reason for leaving a gap between rows. Do you know what this space is for? (Note: If you cannot answer this question ask your instructor.)

j. What is the minimum number of persons required to manually raise a collector to the roof and position it on the collector supports? ______________

k. A specially designed triangularly shaped angle iron tool with a pulley attached is described for pulling the collectors to the roof supports with a rope. How is this tool designed to be held on the roof while pulling up a collector?

l. What prevents the collector from tearing loose shingles or snagging on the collector supports while it is being pulled to the roof?

m. True False -- The collector must be installed with the flow tubes running in a horizontal direction.

n. True False -- Because all other collectors in a row are set in relation to the first one installed, the left most collector in the row is set first.

o. True False -- It is important that the first collector set in place does not deviate more than one degree from level.

p. True False -- The collector is temporarily held in place while it is being leveled by nailing a small brace board to the bottom support.

q. True False -- Collectors are covered after installation and remain covered until put into operation to prevent overheating the "dry" collectors.

r. After leveling and fastening the first collector in position, how do you determine that the next collector is properly aligned/leveled?

s. True False -- The purpose of spacing between collectors is to allow thermal expansion.

t. True False -- The recommended spacing between collectors is 1/16 to 1/8 inch.

Answer the study questions below:

a. Why is it best to avoid the use of high pressure rubber hoses to attach the manifold to pipes or to collectors?

b. Where must an air vent valve be installed in the system?
____

c. What is the purpose of the air vent valve?__________________
____

d. Three possible array circuits which can be used are:

1. ____
2. ____
3. ____

e. Why are parallel flow-direct return circuits not usually used? ____
____

f. True False -- A parallel flow-direct return circuit is easily balanced if a manual valve is placed in the return manifold at each collector connection.

g. True False -- Series flow is used when a higher output temperature from the collector system is desired.

h. True False -- In large planar arrays more piping is required for headers and manifolds than would be required with a parallel system.

i. True False -- In a properly designed system using parallel reverse flow, balancing is seldom required since flow through each collector is the same.

j. True False -- Open loop systems are normally used only where sub-freezing temperatures are rare.

k. Open loop systems must have provisions for draindown in freezing or near freezing weather. To insure adequate drainage, what should be the pitch in horizontal piping runs?

l. What type of system is normally used in cold climates?

____

m. What is the major difference between a closed loop and open loop system?

n. True False -- An advantage of the closed loop system is that the amount of antifreeze required is small since only the fluid in the collector-heat exchanger loop must be protected from freezing.

o. The purpose of an expansion tank in a closed loop system is

____

____.

p. Piping should be sized so that water velocity does not exceed _______ feet per second.

q. How can you prevent electrolytic action between dissimilar metal pipes which must be connected?

Answer the study questions below:

a. In a closed loop system the collector manifolds not only join the collectors to each other, but also join the collectors to the loop through the _____________ _____________.

b. True False -- Two qualities of outside plumbing are neatness and shortness of runs.

c. True False -- Circuit isolation and component servicing are facilitated by providing adequate shut off valves and unions.

d. True False -- Throttling valves should be installed upstream of a fixture whenever possible.

e. True False -- Piping should be sized for high velocities to decrease pumping requirements.

f. True False -- Piping should be pitched up to 1/16 to 1/8 inch per foot to facilitate drainage.

g. True False -- Exit ends of drain pipes must be threaded.

h. Minimum velocity for downcomer pipes should be at least _______ feet per second.

JOB SHEET SC-5-1

FABRICATING AND TESTING A SIMULATED COLLECTOR MANIFOLD

Materials:

1 Ea.	40-inch length of one-inch diameter Type L copper tubing
2 Ea.	5/8-inch male pipe thread x ½-inch hosebarb brass fittings
2 Ea.	One inch ID copper end caps
2 Ea.	6-inch long section of ½-inch ID heavy wall rubber hose
4 Ea.	screw type hose clamps
1 Ea.	½-inch diameter bolt, 1½-inches long
	95-5 solder and 1/16-inch brass brazing rod
	Wire and rags for cleaning pipe
	Sand paper and/or emery cloth for cleaning pipe and fittings

Equipment:

Vise
Oxy-acetylene torch
Hammer
Center punch
Screwdriver
Source of 100 psi air
Brush and soap solution
Knife or deburring tool
Drill motor or drill-press, drill vice, and drill properly sized for holes for hose barbs
Safety goggles for brazing

*Note: Male pipe threads must be removed. Students will machine threads off of brass fittings or instructor will have threadless fittings available.

Procedure:

1. Ream and clean pipe ends. (See Figure 9-18, p. 9-15, "Fundamentals.")

2. Place the copper tubing in the bench vise and tighten snugly, but do not use pressure that will crush tubing. (See the first figure of p. 29 of the Installation chapter in "Lennox.") Measure off a 2-inch distance and a 38-inch distance from one end of the pipe and mark these distances.

3. Align the tubing in the vise so that one of the marks is centered and use the hammer and center punch to make a starting mark for the drill.

4. Carefully move the pipe to center the second mark without rotating the pipe. Be sure the second position to be punched is aligned with the first and use the hammer and punch to make a starting mark for the drill.

5. If available, a drill-press and drill vise should be used to drill perfectly aligned holes. However, if you are fabricating a manifold at the installation site, you may not have access to a drill-press and may be required to use a portable drill. Your instructor will decide which method you use.

6. If using a portable drill, position the tubing carefully in the bench vise and making certain that the drill is vertical, drill a hole into the tubing as shown in the top right photograph on page 29 of the "Lennox" manual installation chapter.

7. Repeat step #6 for the second hole.

8. Ream both holes and clean the area around the holes with sand paper.

9. Clean the brass fittings with sand paper.

   Note: It is assumed that the student is familiar with brazing and soldering techniques and with the lighting and adjusting of an oxy-acetylene torch from previous course work. If you do not have this training, you should not proceed with this exercise.

10. Position the tube and hose barb in the vise as shown in the center picture of page 29 of the Installation chapter of the "Lennox" manual.

11. Light and adjust the oxy-acetylene torch for brazing.

12. Braze the fitting into the pipe.

13. Repeat steps 10 through 12 for the second fitting.

14. Allow the tube to cool then pull a rag attached to a wire through the pipe as shown in the bottom right picture on page 29 to remove any debris.

15. Using the torch adjusted for soldering, use a 95-5 solder to solder the ends cap in each end of the copper tube. Be sure to clean both tube and caps with sand paper prior to soldering. (See first picture on page 30 on Installation chapter in "Lennox" manual).

16. At this point, your instructor will check all joints.

17. If the instructor finds your soldered and brazed joints satisfactory, you are to proceed with an air pressure testing. If joints are not satisfactory, you must remake them and have them rechecked by the instructor.

18. Push the six-inch length of rubber hose onto one of the hose barbs.

19. Place one of the screw type hose clamps over the hose and slide it down near the end of the rubber hose. BE SURE ALL OF THE AREA OF THE HOSE CLAMP IS OVER THE HOSE BARB, TIGHTENING THE CLAMP SECURELY WITH A SCREW DRIVER.

20. Place a second hose clamp over the hose, then push the ½-inch bolt completely into the open end of the hose so only the head of the bolt is exposed. (See Figure at bottom of page 30, Installation chapter of "Lennox" manual.)

21. Pull the hose clamp up over the bolt so that it completely contacts the area of hose over the bolt area, and tighten the screw clamp securely with the screw driver.

22. Attach an air hose directly to the other hose barb or repeat steps 18 to 21 then attach air hose with metal barb coupling to the short length of hose as shown in the center picture of page 30 of the Installation chapter of Lennox manual.

23. IMPORTANT: BE SURE YOUR SET-UP IS IN AN ISOLATED AREA AND THAT SUFFICIENT PROTECTION IS PLACED AROUND IT SO THAT NO ONE CAN BE HURT BY FLYING PARTS IN CASE OF JOINT FAILURE. HAVE YOUR INSTRUCTOR CHECK YOUR SET-UP BEFORE PROCEEDING TO NEXT STEP.

24. After your instructor has checked your set-up for safety, slowly raise the air pressure to 100 psi. (Note the bottom picture on page 30 of "Installation," Lennox manual. This picture could be misleading. Be sure that head , hands, and all body parts are out of the direct line of the bolt inserted in the rubber hose in the event of any material failure while applying the soap solution and watching for bubbles. Check joints and end caps for leaks.

25. Your instructor will be observing while you make leak tests.

26. If leaks are found, they must be corrected by re-doing that portion of the work where leaks are found.

27. After instructor has checked work and found it satisfactory, do the following: Cut off air source and slowly release air pressure. If there is no separate air release valve, loosen very slowly, the clamp on the air hose and allow pressure to leak down before completely removing.

28. Clean up area and put away all tools and materials.

Answer the study questions below:

a. True False -- It is not important that air vents be exactly vertical to operate properly.

b. True False -- Piping runs are braced by the collector supplorts to add stability and neatness to the installation.

c. After completing piping runs through the roof jack and insulating the pipes, the roof jack should be filled with _______________.

d. True False -- The purpose of filling the roof jack is to limit leakage possibilities.

e. How is the hole size to be cut through the roof determined?

f. How thick is the foam insulation that is placed around the pipes? _______________

g. How is the insulation placed around the pipes? ____________
____

h. How are the split pieces of insulation put back together?
____

PREPARING A ROOF PENETRATION FOR COLLECTOR PIPING LINES

Materials:

The 2x2 foot simulated roof section from previous laboratory exercise.
Sheet metal for roof jack - roofing nails
Roofing cement, caulking gun, putty knife, rags, mineral spirits
Tar to fill roof jack
4 6" copper pipe lengths assembled with elbows to form two ell-shaped pieces
4 Pieces of insulation for pipes above

Equipment:

Hammer
Chalk
Drill motor and 3/8-inch drill
Saws all or saber saw

Procedure:

1. Select an area free of rafters or cross bracing (It may be necessary to remove some of the blocking from the previous experiment to find a large enough area.)

2. Use two short pieces of insulation to size the hole. (See lower left picture page 32, Installation Chapter, Lennox Manual.

3. Outline the hole to be cut on the roofing with chalk.

4. Use the drill to prepare a starter hole for the saw.

5. Saw out the outline penetrating roofing felt and plywood sheathing. (See center picture, page 32.)

6. Use a pre-fabricated roof jack or fabricate one to size from sheet metal. (If you do not have previous sheet metal experience, your instructor will advise you.)

7. Center the roof jack over the hole you have cut in the roof. If your roof section is shingled, place the upper edge of the roof jack flashing under the shingles. If it is rolled with roll roofing, nail at all four corners and with two nails equidistant from the corners in all four edges.

8. Seal the edges with roofing cement using a caulking gun or putty knife.

9. Insert ell-shaped pipes with insulation in place.
10. Have instructor check work before filling with tar.
11. Fill roof jack with tar or roofing cement and allow to harden.
12. Clean up tools and return them to storage.

EXAMINATION OF A SOLAR COLLECTOR INSTALLATION

In this exercise, you will make a step-by-step examination of an assembled solar space heating or hot water system at your school. You will examine with your instructor the collector array and the associated plumbing and answer the questions as listed.

IF THE SYSTEM IS OPERATIONAL, BE CAREFUL NOT TO TOUCH HOT COMPONENTS!

Equipment: Inclinometer, tape measure or pocket ruler or protractor

Notice the number of collectors in the array.

Notice the angle at which they are tilted and the method used for supporting them. If possible, measure the angle of inclination; if not, ask your instructor for the angle.

1. Based on the angle, what is the system set up for?

If there is no flashing or trim between collectors, note the spacing. If it is covered you may not be able to see this.

2. What is the purpose of spacing between the collectors?

Note the direction the liquid tubes are running in the collectors.

3. Are the collectors set up with the flow tubes located properly?

Note the incoming piping, the inlet and exit headers (manifolds).

4. What is the circuit arrangement?

Note the manifold-to-collector connections. Are they made with silicone rubber hose or flexible copper tubing?

5. What is the purpose of the offset and bend in the manifold-to-collector connection?

Note the number of air vents and their location.

6. What is the correct location for an air vent?

Note the return pipes and the building penetration. What type of penetration and sealing technique is used?

SOLAR HEATING SYSTEMS CURRICULUM
UNIT LISTING

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SA-2	Describe basic solar system components and their functions.

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Unit	Task
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SB-5	Recommend control devices.
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SB-8	Size solar system components.
SB-9	Perform a solar system economic analysis.
SB-10	Recommend a domestic hot water system.

PHASE C: INSTALLATION

Unit	Task
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SC-5	Install liquid collectors and outside plumbing.
SC-6	Install inside plumbing for collector load side loops.
SC-7	Install controls and wiring.
SC-8	Start up system.

PHASE D MAINTENANCE

Unit	Task
SD-1	Maintain the solar system.
SD-2	Troubleshoot solar system problems

MAJOR BLOCK Solar Systems (Phase C: Installation) NAME ________

TASK Install Inside Plumbing for Collector Load Side Loops

UNIT SC-6 TIME (est.) ________ (act.) ________

OBJECTIVE(S) The student will be able to:

1. Understand and trace collector and load side fluid loops
2. Install all inside plumbing for a solar space heating/ domestic hot water system.

START	➔	W-1	L-1	W-2	L-2	W-3	L-3	L-4	C-1
W-4	L-5	L-6	C-2	C-3					

WRITTEN ASSIGNMENT(S)		AUDIOVISUAL(S)	
W-1	Assignment SC-6-1	A-1	
W-2	Assignment SC-6-3	A-2	
W-3	Assignment SC-6-5	A-3	
W-4	Assignment SC-6-7	A-4	
W-5		A-5	
W-6		A-6	
W-7		A-7	

LABORATORY ASSIGNMENT(S)		CHECKPOINT(S)	
L-1	Assignment SC-6-2	C-1	Progress Check (written quiz)
L-2	Assignment SC-6-4	C-2	Progress Check (written quiz)
L-3	Assignment SC-6-6	C-3	Test (written)
L-4	Job Sheet SC-6-1	C-4	
L-5	Assignment SC-6-8	C-5	
L-6	Job Sheet SC-6-2	C-6	
L-7		C-7	
L-8		C-8	
L-9		C-9	

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   Superintendent of Schools
1979

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407

ACTIVITY SEQUENCE SHEET

Activity	Flow Chart Number	Description of Activity
Assignment SC-6-1	W-1	Review *Fundamentals* Manual from last paragraph, pg. 9-9 down through first sentence of pg. 9-11. Study Figure 9-15, pg. 9-12 and Figure 9-17, pg. 9-14.
Assignment SC-6-2	L-1	Answer study questions on Assignment Sheet SC-6-2.
Assignment SC-6-3	W-2	Read *Lennox Solar Manual*, "Installation" Chapter, pp. 35-36. Study Figure on pg. 23.
Assignment SC-6-4	L-2	Answer study questions on Assignment Sheet SC-6-4.
Assignment SC-6-5	W-3	Read *Fundamentals* Manual, p. 9-24 to 9-26, from "Domestic Water Heating" down to "Drain Down System."
Assignment SC-6-6	L-3	Answer study questions on Assignment Sheet SC-6-6.
Job Sheet SC-6-1	L-4	Complete exercise on Job Sheet SC-6-1.
Progress Check	C-1	Written quiz.
Assignment SC-6-7	W-4	Read *Lennox Solar Manual*, "Installation" Chapter, pp. 37-40. Review Component List, p. 24.
Assignment SC-6-8	L-5	Answer study questions on Assignment Sheet SC-6-8.
Job Sheet SC-6-2	L-6	Complete exercise on Job Sheet SC-6-2.
Progress Check	C-2	Written quiz.
Test	C-3	Written Unit Test.

Answer the study questions below:

The primary system you will be studying as a model for installation in this unit is the closed loop system. However, there will be many installations, particularly in the Southern states, where open loop systems will be used. It is important that you understand the difference between the two systems and how installation procedures differ.

a. T F "Closed loop" means the heat transfer fluid flows through the collectors, through a heat exchanger and an air separator, and is then pumped back to the collectors.

b. T F In a closed loop system the storage water is pumped from the bottom of the tank through the heat exchanger and back to an opening near the top of the tank.

c. T F In the heat exchanger, water from the collectors mixes with a portion of the water from storage to raise the temperature of the storage water.

d. T F Closed loop means that there are no air vents in the loop from collectors to heat exchangers and back.

e. T F In an open loop system, water is used as it comes from the cold water supply system of the building and is circulated throughout the entire circuit.

Note: The previous reading assignment utilizes the term expansion tank, while Figure 9-15 shows two compression tanks in the two loops. These are the same items.

f. In a closed loop system, water in the collectors and the outside loop is kept from freezing by mixing ______________ with the water.

g. Where is a convenient place to add antifreeze in the collector-heat exchanger loop?

h. What is the main purpose of the expansion/compression tanks shown in both loops of the closed loop system?

i. What is the recommended pressure head on the intake side of the pumps?

j. How does the requirement of the previous question affect the location of pumps and storage containers in the load side loop?

Answer the study questions below:

a. The figure on page 35 (Lennox Solar Manual) shows a completed collector fluid loop(inside). The initial step in plumbing the inside portion of the collector fluid loop is ____________
____.

b. The collector fluid loop (inside) is also given another name. What is this name?

c. After marking location of components on the wall and constructing and installing brackets the next step is to install and ______________ the major components.

d. What major component is placed at the highest point in the collector fluid loop (inside)?

e. T F If the heat exchanger is marked as to inlet and outlet sides, it makes no difference which way it is installed.

f. Why are purge lines located outside the structure not insulated?

g. What must be installed in the line when there is a transition from copper pipe to an iron component?

h. How do you "isolate" main components in a loop?

i. What is the name of the line that runs through a cross-fitting from the compression tank fitting to a hose faucet?

j. T F In the parallel "Z or reverse" flow piping arrangement, only one supply line is required regardless of the number of rows of collectors.

k. The valve installed in each collector supply line to regulate flow is known as a ______________ ______________.

Answer the study questions below:

a. T F The guidelines for installing domestic water heating systems differ drastically from those for space heating systems.

b. T F Local building codes safety measures may affect installation requirements to protect the potable water supply.

c. What is the maximum collector pressure rating?

d. T F The main storage tank should be placed directly on the floor for stability.

e. What type of pump is suitable for the fluid loop in a closed loop system?

f. Name two things that can be done to decrease the load on the pump.

1)

2)

g. List the major components found in a domestic hot water typical collector fluid loop (inside)?

h. What materials are acceptable as antifreeze?

The purpose of this exercise is to analyze the organization and functioning of the inside plumbing of a solar system. Although systems vary from each other to some extent, each system must include certain basic functions. Analyze the system available in your school by performing the following instructions.

1. Beginning outside at the collectors, trace the return piping to the inside of the building, to the storage tank, and back to the collectors.
2. Identify the system, as required on the following sheet.
3. On the following page, list the components present in the system loop, and the function of each.
4. Describe on the following sheet the way in which each component was installed (connected in the loop). Note any special procedures used to prevent corrosion, leakage, and other undesirable conditions.
5. Compare the system you are examining to the systems diagrammed in Fundamentals (for space water-heating systems, Figures 9-15 and 9-16, p. 9-12; for water-heating systems, Figure 9-41, page 9-25).
6. On the following pages, list differences between the system you are analyzing, and the one diagrammed. Indicate why each difference can exist, yet both systems can still function.

Type of system:

Type of plumbing loop:

Component	Technique for Installation	Function

Differences between examined system and diagrammed system:

Answer the study questions below:

a. What is the first step in installing load side loops?

b. What are the major components of the load side loop.

1)

2)

3)

4)

c. What material is used for the domestic hot water preheat coil?

d. How is the preheat coil formed?

e. What type of fitting is used to hold the preheat coil in the tank?

f. When is insulation applied to the storage tank?

g. Where on a conventional furnace is the solar heat coil placed?

h. Where should you mount the pumps which circulate hot water between storage and the solar heat coil?

i. Where is a manual bleed valve placed in the load side loop?

In this exercise you will trace the load side loop for the solar system in your school.

If the system is set up for space heating and domestic hot water, you are to trace all loops starting from and returning to the tank for both hot water and space heating.

If the system is set up only for hot water, trace the plumbing to the conventional hot water heater, then move to the incoming cold water line and trace the plumbing back to the storage tank.

Identify every component including all valves and vents and describe their purpose to your Instructor.

Do not identify any components that are part of the collector fluid loop.

SOLAR HEATING SYSTEMS CURRICULUM
UNIT LISTING

PHASE A: BASIC UNDERSTANDING

Unit	Task
SA-1	Explain the value of solar energy and principles of solar radiation.
SA-2	Describe basic solar system components and their functions.

PHASE B: DESIGN

Unit	Task
SB-1	Recommend non-solar energy conservation measures.
SB-2	Select passive solar approaches for new construction.
SB-3	Recommend collectors.
SB-4	Recommend and site the thermal storage unit.
SB-5	Recommend control devices.
SB-6	Recognize and describe modes of solar system operation.
SB-7	Calculate heat load for space or domestic hot water heating.
SB-8	Size solar system components.
SB-9	Perform a solar system economic analysis.
SB-10	Recommend a domestic hot water system.

PHASE C: INSTALLATION

Unit	Task
SC-1	Recommend correct thermal mass for direct gain system; fabricate and install modular wall units for passive solar.
SC-2	Schedule solar installation.
SC-3	Install a liquid storage tank.
SC-4	Site and mount collectors.
SC-5	Install liquid collectors and outside plumbing.
SC-6	Install inside plumbing for collector load side loops.
SC-7	Install controls and wiring.
SC-8	Start up system.

PHASE D MAINTENANCE

Unit	Task
SD-1	Maintain the solar system.
SD-2	Troubleshoot solar system problems

MAJOR BLOCK Solar Systems (Phase C: Installation) **NAME**

TASK Install Controls and Wiring

UNIT SC-7 **TIME** (est.) ______ (act.) ______

OBJECTIVE(S) The student will be able to:

1. Describe the functions of all controls and their interrelationships.
2. Wire a liquid closed-loop solar space heating system.

START ➔ W-1 ➔ L-1 ➔ W-2 ➔ L-2 ➔ W-3 ➔ W-4 ➔ C-1 ➔ C-2

WRITTEN ASSIGNMENT(S)

W-1 Assignment SC-7-1
W-2 Assignment SC-7-3
W-3 Information Sheet SC-7-1
W-4 Assignment SC-7-5
W-5
W-6
W-7

LABORATORY ASSIGNMENT(S)

L-1 Assignment SC-7-2
L-2 Assignment SC-7-4
L-3 Job Sheet SC-7-1
L-4
L-5
L-6
L-7
L-8
L-9

AUDIOVISUAL(S)

A-1
A-2
A-3
A-4
A-5
A-6
A-7

CHECKPOINT(S)

C-1 Demonstration & Oral Quiz
C-2 Test
C-3
C-4
C-5
C-6
C-7
C-8
C-9

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ACTIVITY SEQUENCE SHEET

Activity	Flow Chart Number	Description of Activity
Assignment SC-7-1	W-1	Read Lennox Solar Manual, Installation, p. 41-43. Review Lennox Solar Manual, Controls, p. 1-5.
Assignment SC-7-2	L-1	Answer study questions on Assignment Sheet SC-7-2.
Assignment SC-7-3	W-2	Read Lennox Solar Manual, Installation, p. 25 and p. 65-69. Pay particular attention to the control panel diagrams on p. 25 and p. 69.
Assignment SC-7-4	L-2	Answer study questions on Assignment Sheet SC-7-4.
Information Sheet SC-7-1	W-3	Read Information Sheet SC-7-1.
Assignment SC-7-5	W-4	Read Lennox Solar Manual, Installation, p. 70-71.
Checkpoint	C-1	Demonstration and oral quiz.
Job Sheet SC-7-1	L-3	Do activity described on Job Sheet SC-7-1.
Test	C-2	Written.

Answer the study questions below:

1. In wiring the control system, what determines such things as the gauge of wire necessary, the size of fusing and where conduit is needed?

2. In the Honeywell Control System, the control panel chasis contains the following items:

   a.

   b.

   c.

   d.

   e.

   f.

3. Besides accessibility and temperature considerations, what should determine the control panel location?

4. The collector sensor is clamped as close to the collector outlet as possible. To prevent sunshine from impinging directly on the sensor where should it be clamped?

5. How is the sensor wiring routed through the collector?

6. Where is the remote sensing bulb for the purge aquastat control mounted?

7. Where is the storage sensor installed?

8. Where is the storage aquastat installed?

9. To what control inside the control panel are the storage sensor and the collector sensor wired?

10. The control valve which directs fluid to the solar coil or the storage tank is connected electrically via the control panel to three temperature sensors. What are these sensors?

    a.

    b.

    c.

11. A dual-control valve is installed in the collector fluid loop return line and connects to the lines feeding the purge coil. It is connected electrically to the ______________ ______________ and the ______________ ______________.

Answer the study questions below.

1. Grounded metallic conduit and shielded cable wiring should be used for wiring electronic sensors to minimize what possible problem?

2. Where must the shield be connected to ground?

3. For runs exceeding 100 feet from sensor to control panel, what size wire must be used?

4. The control panel must be wired to a 120V AC, 60 hz, 30 amp power supply with overload protection and disconnect means as required by local code.

    a. Which power supply wire attaches to terminal L1?

    b. What wire goes to terminal L2?

5. The solar panel sensor and the storage sensor are wired to the differential temperature controller. Which pressure contacts are used for:

    a. The solar panel sensor?

    b. The storage sensor?

6. The purge aquastat controller is wired to what pressure points?

7. The storage aquastat control is wired to what pressure points?

8. The return air limit control is wired to pressure points FL and L1 which allows it to control valve _______.

9. Pumps P1 and P2 always operate together. Follow the wiring diagram. What turns these two pumps on or off?

10. Pump P3 allows what mode of heating to heat the house?

11. The space thermostat is connected directly to four terminals on the control panel. What are the four terminals?

12. What other components may be connected directly to the thermostat?

13. If the thermostat is used to control heating, only a jumper should be connected between what two points on the thermostat?

14. The fan control and motor are connected to what terminals on the control panel?

15. If a two-pump, three- or four-valve system is installed, how must the control panel be changed?

16. In the two pump, three- or four-valve system, where are valves 3 and 4 connected?

You have been taught plumbing and wiring applications as separate tasks. In actual installation, you may find it more practical to accomplish some of the wiring tasks as the plumbing progresses. Some control installation and wiring must be accomplished prior to insulating the pipes.

The collector sensor must be clamped to the absorber plate or a collector outlet tube. The collector wires must be routed through the collector insulation and out a weep hole at the bottom. It then must run alongside the pipes to a roof penetration. The wire must be in its own metal electrical conduit or shielded with metal braid. All of these steps must be accomplished before the outside pipes are insulated.

Inside, the purge aquastat sensor bulb must be attached to the collector fluid return line before insulation is applied. Likewise, electrical connections must be made on those valves requiring electrical operation before insulating.

Page 42 of the Lennox Solar Manual, Installation Chapter, shows the method of insulating the storage sensor and aquastat sensing bulb so that the bulbs are easily accessible.

WIRING A DOMESTIC HOT WATER SYSTEM

The student will wire the school domestic hot water system.

CAUTION: Anytime the solar system is not circulating fluid, the collectors must be covered to prevent damage.

Before beginning, refer to Lennox Solar Manual, Lennox Domestic Hot Water System, p. 10, Figure 5.

1. The student will check installation of the collector sensor unless it is covered with insulation, which cannot be readily removed.
2. S/he will connect wires leading from control box to sensor leads with wire nuts.
3. Wires, if not already in place, will be run into the building to the proportional controller.
4. Be absolutely certain main power is off, then run wires into the grommeted bottom knockout and connect each wire with wire nuts to the red wires in the proportional controller.
5. Trace the blue wires from the tank sensor into the proportional controller and note that they are factory pre-wired.
6. Connect 120V AC/60Hz/1 phase power supply from fused disconnect to black and white leads in proportional controller with wire nuts.
7. Wiring is complete and system can be put back in operation by a) closing disconnect switch, b) placing controller switch in the auto- position, and c) placing pump switch in 1-dash position.
8. Be sure to uncover collector(s) when system is again operating.

SOLAR HEATING SYSTEMS CURRICULUM
UNIT LISTING

PHASE A: BASIC UNDERSTANDING

Unit	Task
SA-1	Explain the value of solar energy and principles of solar radiation.
SA-2	Describe basic solar system components and their functions.

PHASE B: DESIGN

Unit	Task
SB-1	Recommend non-solar energy conservation measures.
SB-2	Select passive solar approaches for new construction.
SB-3	Recommend collectors.
SB-4	Recommend and site the thermal storage unit.
SB-5	Recommend control devices.
SB-6	Recognize and describe modes of solar system operation.
SB-7	Calculate heat load for space or domestic hot water heating.
SB-8	Size solar system components.
SB-9	Perform a solar system economic analysis.
SB-10	Recommend a domestic hot water system.

PHASE C: INSTALLATION

Unit	Task
SC-1	Recommend correct thermal mass for direct gain system; fabricate and install modular wall units for passive solar.
SC-2	Schedule solar installation.
SC-3	Install a liquid storage tank.
SC-4	Site and mount collectors.
SC-5	Install liquid collectors and outside plumbing.
SC-6	Install inside plumbing for collector load side loops.
SC-7	Install controls and wiring.
SC-8	Start up system.

PHASE D MAINTENANCE

Unit	Task
SD-1	Maintain the solar system.
SD-2	Troubleshoot solar system problems

MAJOR BLOCK Solar Systems (Phase C: Installation) NAME ____________

TASK System Start Up

UNIT SC-8 TIME (est.) ________ (act.) ______

OBJECTIVE(S) The student will be able to:

1. Fill and flush the solar system
2. Test for leaks
3. Repair leaks
4. Charge the system and balance flows
5. Put the system into operation.

START	➔	W-1	L-1	W-2	L-2	W-3	L-3	L-4	C-1

WRITTEN ASSIGNMENT(S)		AUDIOVISUAL(S)	
W-1	Assignment SC-8-1	A-1	
W-2	Assignment SC-8-3	A-2	
W-3	Assignment SC-8-5	A-3	
W-4		A-4	
W-5		A-5	
W-6		A-6	
W-7		A-7	

LABORATORY ASSIGNMENT(S)		CHECKPOINT(S)	
L-1	Assignment SC-8-2	C-1	Observation
L-2	Assignment SC-8-4	C-2	Test
L-3	Assignment SC-8-6	C-3	
L-4	Job Sheet SC-8-1	C-4	
L-5		C-5	
L-6		C-6	
L-7		C-7	
L-8		C-8	
L-9		C-9	

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ACTIVITY SEQUENCE SHEET

Activity	Flow Chart Number	Description of Activity
Assignment SC-8-1	W-1	Read Lennox Solar Manual, "Installation," "System Start-Up," p. 45-47, down to "Charging the Collector Fluid Loop."
Assignment SC-8-2	L-1	Answer study questions on Assignment Sheet SC-8-2.
Assignment SC-8-3	W-2	Read Lennox Solar Manual, "Installation," "Charging the Collector Fluid Loop," p. 47.
Assignment SC-8-4	L-2	Answer study questions on Assignment Sheet SC-8-4.
Assignment SC-8-5	W-3	Read Lennox Solar Manual, "Installation," p. 48-49.
Assignment SC-8-6	L-3	Answer study questions on Assignment Sheet SC-8-6.
Job Sheet SC-8-1	L-4	Do activity described on Job Sheet SC-8-1.
Observation	C-1	Accomplish the activity described on Job Sheet SC-8-1 under direct supervision of the Instructor.
Test	C-2	Written.

1. T F There is only one specific time in the installation procedure when insulation should be applied to the pipes.

2. T F Since water is used to flush the system, it is the most convenient medium for leak-testing.

3. T F Water is more likely to leak out of the system than is an ethylene glycol water mixture.

4. T F A single flushing of the system is sufficient.

5. T F Before beginning the filling operation, all valves in the collector fluid loop should be open except the valve in the drain line.

6. T F All toggle switches inside the panel should be in the "on" position.

7. T F The pressure relief valve can be capped to raise the system pressure to 50 psi for a better check during leak-testing.

8. T F For quicker bleeding of air, the stems of automatic vents can be depressed intermittently.

9. T F The purge lines and coil are filled by energizing valve V1.

10. T F After filling to desired pressure, the system should be drained.Leaving air vents closed will expedite the draining.

11. T F After refilling the system and energizing the purge valve, pump P1 should be energized and water circulated for two hours.

12. There are two ways to check for leaks. One is a visual inspection of all soldered joints. What is the other?

13. T F After draining the system and repairing any leaks there is no reason to refill system to check the repaired areas.

14. After satisfaction with soundness of the system, the final three steps after draining are:

    a.

    b.

    c.

Answer the study questions below.

1. The first step in preparing to charge the collector fluid loop is to ____.

2. T F The fill mixture for the collector fluid loop should be 50-50 ethylene glycol-water. NOTE: The manual does not so state, but the water used in charging the collector loop should be distilled water.

3. What causes the system pressure to drop from the desired 12 psig after filling the system?

4. After system pressure is stabilized,how is final flow balance accomplished?

Answer the study questions below.

1. T F Before beginning flushing and charging up the load side loops, power should be available to the control panel and all switches inside the panel should be in the "stop" position.

2. T F All valves including gate, globe, air vent and circuit setters in the load side loops should be open.

3. After filling the storage tank, what steps besides bleeding air are necessary to fill the heat exchanger to storage loop?

4. Other than bleeding air, what step is necessary to fill the heat exchanger to space heating loop?

5. What steps are necessary to fill the storage to space heating loop?

6. The storage tank, water heater and most of the plumbing is drained by opening the drain valves on the two tanks. What is necessary to drain the solar heat coil?

7. What is the approximate time necessary to circulate water in each loop after refilling to properly leak test the load side loops?

8. What component is useful in determining the proper fill level for the storage tank?

9. T F One of the final steps in preparing the load side loops for operation is to set the tempering valve for the desired hot water temperature.

10. T F Balancing of the circuit setters is accomplished in the same manner as with the collector fluid loop.

11. T F The final step after setting and adjusting all controls is to uncover the collectors.

CHARGING A CLOSED LOOP SOLAR SYSTEM

NOTE: This exercise is designed for use with the Lennox AP-4 Solar System Trainer Kit. It assumes that the Trainer is fully and correctly installed and ready for charging.

In charging the system, the student will work under direct supervision of the Instructor and will answer the Instructor's questions as s/he performs the steps listed below.

Charging the System

NOTE: Make sure the collector is covered or shaded from direct radiant heat while charging the system.

A. Collector Loop

1. The transfer fluid in the collector loop should be a 50% distilled water, 50% ethylene glycol solution by volume. Premix and keep on hand a quantity of this solution in a covered container.
2. Place hose from inlet side of charging pump into container of transfer fluid solution.
3. Connect hose from outlet side of charging pump to collector drain valve.
4. Open collector drain valve and gate valve Nos. 2 & 3.
5. Start charging pump.
6. Bleed air from air vents Nos. 1, 2, 3 and 4.
7. Charge the system until the collector loop pressure gauge stabilizes (15 to 19 psi).
8. Close collector drain valve and shut off charging pump.
9. Remove charging pump and hoses.
10. Adjust flow meter between .4 and .7 GPM.

B. Load Loop

1. Fill trainer storage tank with water just below the return line to the tank (approximately 5 gallons).

2. Close gate valves Nos. 1 & 4. Turn "ON" fused disconnect switch.

3. Prime pump P2 by removing cap from air vent No. 5. Pour a small quantity of water (approximately one pint) through the air vent opening. This permits water to drain into the chamber of pump P2.

4. Replace air vent cap.

5. Flip switch on controller to the "ON" position to start pump P2 and slowly open gate valves Nos. 1 & 4.

6. Open cap on air vent No. 5 one-half turn. If fluid spurts from the vent, the pump is primed and fluid is circulating through the load loop. If fluid is not present at the vent, pump is not primed and steps 2 through 6 must be repeated.

FLUSHING AND FILLING A DOMESTIC HOT WATER SYSTEM

NOTE: This exercise is designed for a completely installed and working hot water system such as the Lennox Domestic Hot Water System (LSHW1 Series).

In flushing and filling the system, the student will work under direct supervision of the Instructor and will answer the Instructor's questions while performing all of the steps outlined below. The student will follow the step-by-step procedure on pages 16-17 of the LSHW1 Solar Water Heating Systems section of the Lennox Solar Manual.

SOLAR HEATING SYSTEMS CURRICULUM
UNIT LISTING

PHASE A: BASIC UNDERSTANDING

Unit	Task
SA-1	Explain the value of solar energy and principles of solar radiation.
SA-2	Describe basic solar system components and their functions.

PHASE B: DESIGN

Unit	Task
SB-1	Recommend non-solar energy conservation measures.
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SB-6	Recognize and describe modes of solar system operation.
SB-7	Calculate heat load for space or domestic hot water heating.
SB-8	Size solar system components.
SB-9	Perform a solar system economic analysis.
SB-10	Recommend a domestic hot water system.

PHASE C: INSTALLATION

Unit	Task
SC-1	Recommend correct thermal mass for direct gain system; fabricate and install modular wall units for passive solar.
SC-2	Schedule solar installation.
SC-3	Install a liquid storage tank.
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SC-5	Install liquid collectors and outside plumbing.
SC-6	Install inside plumbing for collector load side loops.
SC-7	Install controls and wiring.
SC-8	Start up system.

PHASE D MAINTENANCE

Unit	Task
SD-1	Maintain the solar system.
SD-2	Troubleshoot solar system problems

MAJOR BLOCK Solar Systems (Phase D: Maintenance) **NAME**

TASK Maintenance

UNIT SD-1 **TIME** (est.) (act.)

OBJECTIVE(S) The student will be able to:

1. Explain to a customer the purpose and need for scheduled maintenance.
2. Construct a maintenance schedule for a particular system.
3. Conduct system maintenance prescribed by component manufacturer.

START ➡ W-1 W-2 L-1 C-1 L-2 C-2

WRITTEN ASSIGNMENT(S)

W-1 Information Sheet SD-1-1
W-2 Assignment SD-1-1
W-3
W-4
W-5
W-6
W-7

LABORATORY ASSIGNMENT(S)

L-1 Assignment SD-1-2
L-2 Job Sheet SD-1-1
L-3
L-4
L-5
L-6
L-7
L-8
L-9

AUDIOVISUAL(S)

A-1
A-2
A-3
A-4
A-5
A-6
A-7

CHECKPOINT(S)

C-1 Progress Check (written)
C-2 Test (written)
C-3
C-4
C-5
C-6
C-7
C-8
C-9

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ACTIVITY SEQUENCE SHEET

Activity	Flow Chart Number	Description of Activity
Information Sheet SD-1-1	W-1	Read Information Sheet SD-1-1.
Assignment SD-1-1	W-2	Read Fundamentals Manual, p. 10-5 to 10-9, from "Periodic Maintenance" down to "Troubleshooting."
Assignment SD-1-2	L-1	Answer study questions on Assignment Sheet SD-1-2.
Progress Check	C-1	Instructor check (written)
Job Sheet SD-1-1	L-2	Do exercise on Job Sheet SD-1-1.
Test	C-2	Written.

At the completion of the solar installation, the owner should be provided with an "owner's manual." The manual could be simple, consisting of several typewritten sheets, or it could be a comprehensive notebook, containing detailed literature on all components in the system. The knowledgeable homeowner will appreciate the more comprehensive notebook.

Such a manual can be just as important to the contractor as to the homeowner because it should discourage tampering with the system and reduce the number of callbacks for service that is not necessary. An owner who understands his system can often detect minor problems before they become serious.

Some, but not all, of the items that could be included in the owners manual are:

-installation instructions
-start-up instructions
-operating instructions
-maintenance instructions
-safety precautions
-warranty information

It is particularly important to point out the maintenance activities that the homeowner can and may conduct himself. Some of these items are:

a. Check liquid levels at prescribed periods.
b. Change air filters when required.
c. Change liquid filters.
d. Check and change blower drive belts if worn.
e. Lubricate pumps at intervals suggested by manufacturer.
f. Check liquid levels weekly for first month and at any time after the power has been off.

Remember that each homeowner is a different individual. The maintenance that one homeowner can conduct easily and correctly may be too difficult for another. The serviceman should be prepared to offer a series of service packages to satisfy the requirements of all homeowners.

Other items which require special equipment and training should be offered the homeowner in an annual service check. Some of these items are checking the antifreeze and inspection by disassembly of collectors, valves and electrical components.

The student is cautioned not to use the suggested service intervals listed in the Fundamentals Manual, p. 10-5 under Periodic Maintenance. These are typical intervals, but the student should rely instead on the intervals suggested in the service and installation manuals provided with the particular components installed.

Answer the study questions below.

1. While inspecting collector cover plates, what items are you looking for?

2. In visually inspecting the absorber plates of a closed-tube liquid collector, two items should be looked for. What are these?

   a.

   b.

3. What should you look for with regard to the absorber sensor?

4. Name two methods you can use to determine if a collector is operating properly.

   a.

   b.

5. How would you determine the best method for repair of a particular absorber coating?

6. How would you correct the problem of liquid tubes pulled loose from the absorber plate?

7. What do you look for in examining insulated liquid transfer pipes?

8. Can all valves be determined to be working properly by a visual outside inspection?

NOTE: Solid state electronic controls are generally reliable and require maintenance only if not working. The procedures used to isolate a problem with the electronic system will be covered in the next unit on trouble-shooting.

Using your approved checklist, perform maintenance activities required on the school system under direction of your Instructor.

NOTE: DO NOT DRAIN AND FLUSH COLLECTOR LOOP WITHOUT SPECIFIC INSTRUCTION TO DO SO.

SOLAR HEATING SYSTEMS CURRICULUM
UNIT LISTING

PHASE A: BASIC UNDERSTANDING

Unit	Task
SA-1	Explain the value of solar energy and principles of solar radiation.
SA-2	Describe basic solar system components and their functions.

PHASE B: DESIGN

Unit	Task
SB-1	Recommend non-solar energy conservation measures.
SB-2	Select passive solar approaches for new construction.
SB-3	Recommend collectors.
SB-4	Recommend and site the thermal storage unit.
SB-5	Recommend control devices.
SB-6	Recognize and describe modes of solar system operation.
SB-7	Calculate heat load for space or domestic hot water heating.
SB-8	Size solar system components.
SB-9	Perform a solar system economic analysis.
SB-10	Recommend a domestic hot water system.

PHASE C: INSTALLATION

Unit	Task
SC-1	Recommend correct thermal mass for direct gain system; fabricate and install modular wall units for passive solar.
SC-2	Schedule solar installation.
SC-3	Install a liquid storage tank.
SC-4	Site and mount collectors.
SC-5	Install liquid collectors and outside plumbing.
SC-6	Install inside plumbing for collector load side loops.
SC-7	Install controls and wiring.
SC-8	Start up system.

PHASE D MAINTENANCE

Unit	Task
SD-1	Maintain the solar system.
SD-2	Troubleshoot solar system problems

MAJOR BLOCK Solar Systems (Phase D: Maintenance) NAME ____________

TASK Trouble Shoot Solar System Problems

UNIT SD-2 TIME (est.) ________ (act.) ________

OBJECTIVE(S) The student will be able to:

1. Determine the symptoms which indicate faulty operation of the system.
2. Check the system to determine cause of each symptom.
3. Correct the faults so the system operates correctly.

START ➡ W-1 L-1 W-2 L-2 L-3 C-1 L-4 C-2 C-3

WRITTEN ASSIGNMENT(S)

W-1 Assignment SD-2-1
W-2 Assignment SD-2-3
W-3 ____________
W-4 ____________
W-5 ____________
W-6 ____________
W-7 ____________

LABORATORY ASSIGNMENT(S)

L-1 Assignment SD-2-2
L-2 Assignment SD-2-4
L-3 Job Sheet SD-2-1
L-4 Job Sheet SD-2-2
L-5 ____________
L-6 ____________
L-7 ____________
L-8 ____________
L-9 ____________

AUDIOVISUAL(S)

A-1 ____________
A-2 ____________
A-3 ____________
A-4 ____________
A-5 ____________
A-6 ____________
A-7 ____________

CHECKPOINT(S)

C-1 Progress Check (oral)
C-2 Progress Check (oral)
C-3 Unit Test (written)
C-4 ____________
C-5 ____________
C-6 ____________
C-7 ____________
C-8 ____________
C-9 ____________

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No person shall, on the basis of sex, race, national origin or handicap, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity under the direction of the local education agency.

447

ACTIVITY SEQUENCE SHEET

Activity	Flow Chart Number	Description of Activity
Assignment SD-2-1	W-1	Review Fundamentals Manual (p. 10-8, 10-11) from "Electronic Controls" down to "Warranties."
Assignment SD-2-2	L-1	Answer study questions on Assignment Sheet SD-2-2.
Assignment SD-2-3	W-2	Read Lennox Solar Manual, "Installation" Chapter (P. 69-73), review "Controls-Components & System Schematics," (p. 5-17).
Assignment SD-2-4	L-2	Answer study questions on Assignment Sheet SD-2-4.
Job Sheet SD-2-1	L-3	Do exercise described on Job Sheet SD-2-1
Progress Check	C-1	Oral quiz.
Job Sheet SD-2-2	L-4	Do exercise described on Job Sheet SD-2-2.
Progress Check	C-2	Oral quiz.
Test	C-3	Written.

Answer the study questions below.

1. The underlying cause of a solar system's failure to perform usually falls into one of four categories. Name these categories.
   1.
   2.
   3.
   4.

2. Of the four categories of malfunction listed above, one is usually the easiest to find and correct. Name this category.

3. There are four main reasons why system parts fail. Name three of these reasons.
   1.
   2.
   3.
   4.

4. What is the danger of changing pulley ratios to greatly increase the velocity of the air blower?

5. What is the best method of preventing wear and tear on moving parts?

6. List four indicators that may tell you a system is out of adjustment.
   1.
   2.
   3.
   4.

7. List three malfunctions which may result in excess noise.
   1.
   2.
   3.

8. What type of parts most often fail because they have been used beyond their rated capacity?

Answer the study questions below.

1. The first step in trouble-shooting the proper operation of the solar control panel is to determine temperatures at the differential temperature controller and the solar aquastat controller sensor. The differential temperature measured at the controller is the difference in temperature between ______________ and ______________.

2. The purpose of the solar aquastat controller is to limit the temperature of the fluid in the collector loop. If the temperature exceeds the set-point, what happens in the system if it is working properly?

3. The collector and storage sensors provide an indication of temperature by a change in resistance. To measure the temperature difference at the differential controller, it is necessary to measure resistance across the terminals using a high resistance ohmeter. How do you determine temperature from these readings?

4. How would you determine the operating temperature at the solar aquastat sensor?

5. You have determined differential temperature and the temperature at the collector aquastat. What is your next step in determining if there is an operating problem with these two controls?

6. The collector sensors are changing resistance with temperature and read correctly on the chart of resistance versus temperature. However, the readings do not agree with separate temperature measurements you have made at the collectors. What must you do to correct this situation?

NORMAL OPERATION OF A TYPICAL SOLAR INSTALLATION ELECTRICAL SYSTEM

MATERIALS:

- Lennox ST-17 Solar Heat Service Trainer
- Small-blade screwdriver
- Medium screwdriver
- Multi-meter
- Needle-nose pliers
- Lennox Solar Manual

PROCEDURE:

The student should be familiar with all normal operating modes of the Lennox ST-17 Solar heat service trainer. This trainer operates in exactly the same manner as an actual system using the Honeywell W968A solar control panel.

The student will use Table 2, p. 70, of the "Installation" chapter of the Lennox Solar Manual and the detailed operation procedures on page 71 and 72 to become familiar with normal operating modes. For each operating mode, the student will go through the steps of disconnecting, adjusting and energizing the component required by Table 2. The student will observe the system response to be sure it is operating as shown in Table 2. Any deviation from expected response will be brought to the attention of the Instructor.

TROUBLE-SHOOTING OF A TYPICAL SOLAR INSTALLATION ELECTRICAL SYSTEM

MATERIALS:

- Lennox ST-17 Solar Heat Service Trainer
- Small-blade screwdriver
- Medium screwdriver
- Multimeter
- Needle-nose pliers
- *Lennox Solar Manual*

PROCEDURE:

The Lennox ST-17 Solar Heat Service Trainer can simulate 144 possible malfunction situations with 13 faults, which can be programmed into each of the operating modes.

The Instructor will select one of the normal modes of operation. With the trainer operating normally, the Instructor will: flip "off" the power switch, flip "on" a selected fault switch. Then flip back "on" the power switch.

The student will then begin the system check-out using the trouble-shooting procedures on page 72 and 73 of the "Installation" chapter of the *Lennox Solar Manual*. After the problem is found and the student has recommended the correct solution, the Instructor will return the fault switch to "off." This procedure will be repeated until the student has correctly recommended the solution for a minimum of ten malfunctions.

SOLAR HEATING SYSTEMS CURRICULUM
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